J M2 / Grant

MSC 02467
CONTRACT NAS9-9953
SD71-237

C-1

CR 115320

N72-13864

MODULAR space station
PHASE B EXTENSION

NASA HEADQUARTERS QUARTERLY REVIEW

PREPARED BY PROGRAM MANAGEMENT

31 August 1971

EV

Space Division
North American Rockwell
12214 LAKEWOOD BOULEVARD
DOWNEY, CALIFORNIA 90241

MSC 02467

SD 71-237

MODULAR SPACE STATION
PHASE B EXTENSION
NASA HEADQUARTERS QUARTERLY REVIEW
Contract NAS9-9953

31 August 1971

Prepared by

Program Management

Approved by

Contractor	NASA
Earl G. Cole	Rene' A. Berglund
Earl G. Cole	Rene' A. Berglund
Program Manager	Manager
Space Station/Orbital Systems	Space Station Project Office

Space Division
North American Rockwell

TECHNICAL REPORT INDEX/ABSTRACT

ACCESSION NUMBER	DOCUMENT SECURITY CLASSIFICATION
	UNCLASSIFIED

TITLE OF DOCUMENT	LIBRARY USE ONLY
MODULAR SPACE STATION PHASE B EXTENSION NASA HEADQUARTERS QUARTERLY REVIEW	

AUTHOR(S)

COLE, E.G. * R.A. BERGLUND * A.A. TISCHLER

CODE	ORIGINATING AGENCY AND OTHER SOURCES	DOCUMENT NUMBER
QN085057	SPACE DIVISION OF NORTH AMERICAN ROCKWELL CORPORATION, DOWNEY, CALIFORNIA	SD71-237

PUBLICATION DATE	CONTRACT NUMBER
31AUG71	NAS9-9953

DESCRIPTIVE TERMS

*SPACE STATION PROGRAM, *PHASE B EXTENSION CONTRACT NAS9-9953

ABSTRACT

THIS DOCUMENT REPRESENTS A COMPILATION OF DATA PRESENTED IN THE SPACE STATION PHASE B EXTENSION STUDY, NASA HEADQUARTERS QUARTERLY REVIEW, PRESENTED 31 AUGUST 1971 AT NASA HEADQUARTERS, WASHINGTON, D.C.

CONTENTS

I. INTRODUCTION

MODULAR SPACE STATION-PHASE B
NASA HEADQUARTERS-QUARTERLY REVIEW

INTRODUCTION

R. BERGLUND

OVERVIEW
SORTIE ANALYSIS
EXPERIMENT ANALYSIS

E.G. COLE

MSS REVIEW
OPERATIONS
SUBSYSTEMS
CONFIGURATIONS

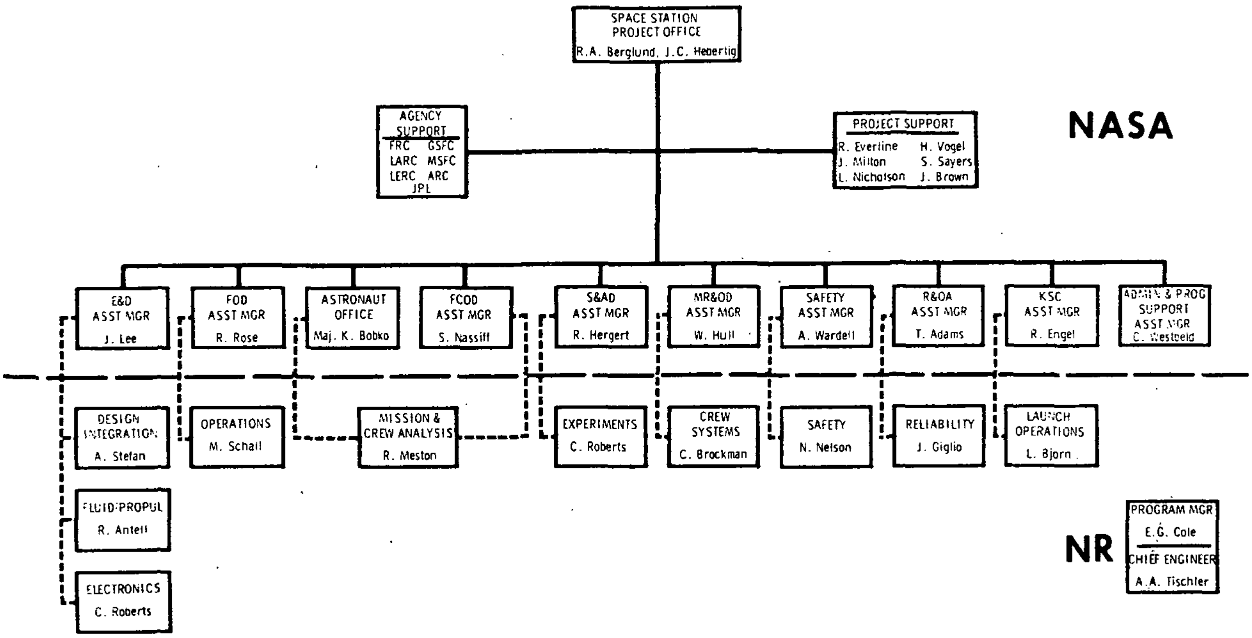
A.A. TISCHLER

FUTURE
ACTIVITIES

E.G. COLE

81PDS110218

NASA / NR ENGINEERING INTERFACES



81PDS110181

There are two primary objectives that have influenced the MSC/Space Station Project Office organization and the manner in which the center interfaces with NR. The first objective is to ensure the center's full technical participation in the study effort and to avail the Study Manager of expertise from other NASA centers. The second basic objective is to provide a mechanism for achieving a combined MSC/NR study product.

These objectives have been met by including within the study team representatives from the field centers and by assigning Assistant Study Managers from each appropriate MSC Center Directorate or Office. The Assistant Study Managers appointed from the technical or scientific organizations work directly with their NR counterparts as indicated by the dotted lines in the chart. These personnel have been assigned the technical responsibility for the study effort, while programmatic responsibility remains within the Project Office. The Project Support Group provides general support to the Study Manager in contract monitoring.

An important point regarding Assistant Study Managers is that they have not been organizationally detached from their respective directorates, which allows them to obtain technical support from within these line organizations as well as guidance from their respective management structures. This approach allows the MSC to supplement and complement the NR technical effort.

II. OVERVIEW—SORTIE ANALYSIS AND EXPERIMENT ANALYSIS

MODULAR SPACE STATION-PHASE B
NASA HEADQUARTERS-QUARTERLY REVIEW

INTRODUCTION

R. BERGLUND

OVERVIEW
SORTIE ANALYSIS
EXPERIMENT ANALYSIS

E.G. COLE

MSS REVIEW
OPERATIONS
SUBSYSTEMS
CONFIGURATIONS

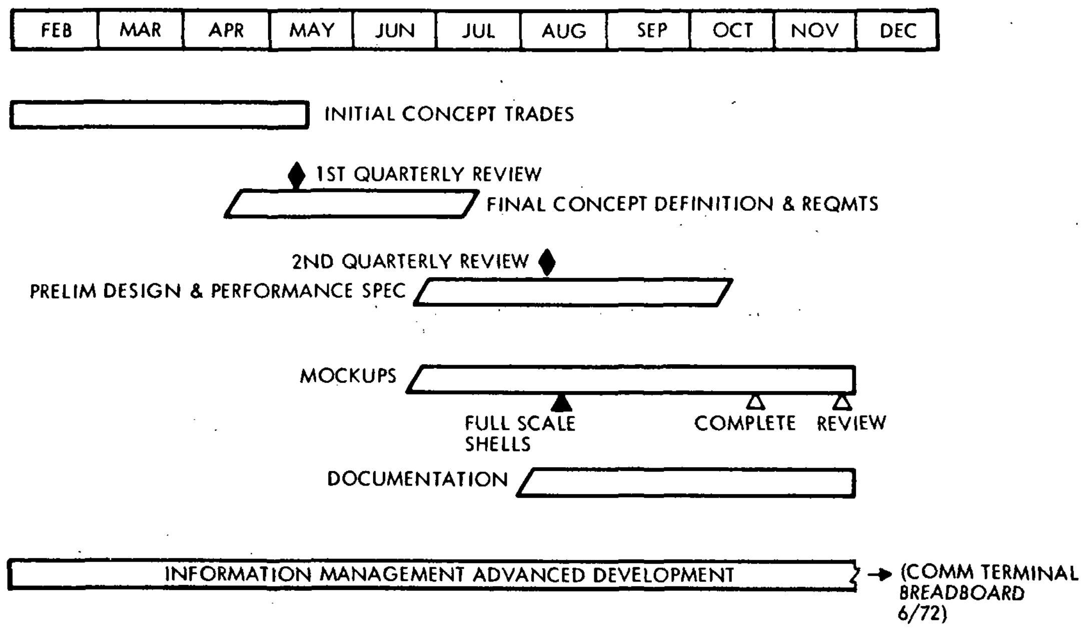
A.A. TISCHLER

FUTURE
ACTIVITIES

E.G. COLE

81PDS110182

MSS PHASE B SUMMARY SCHEDULE

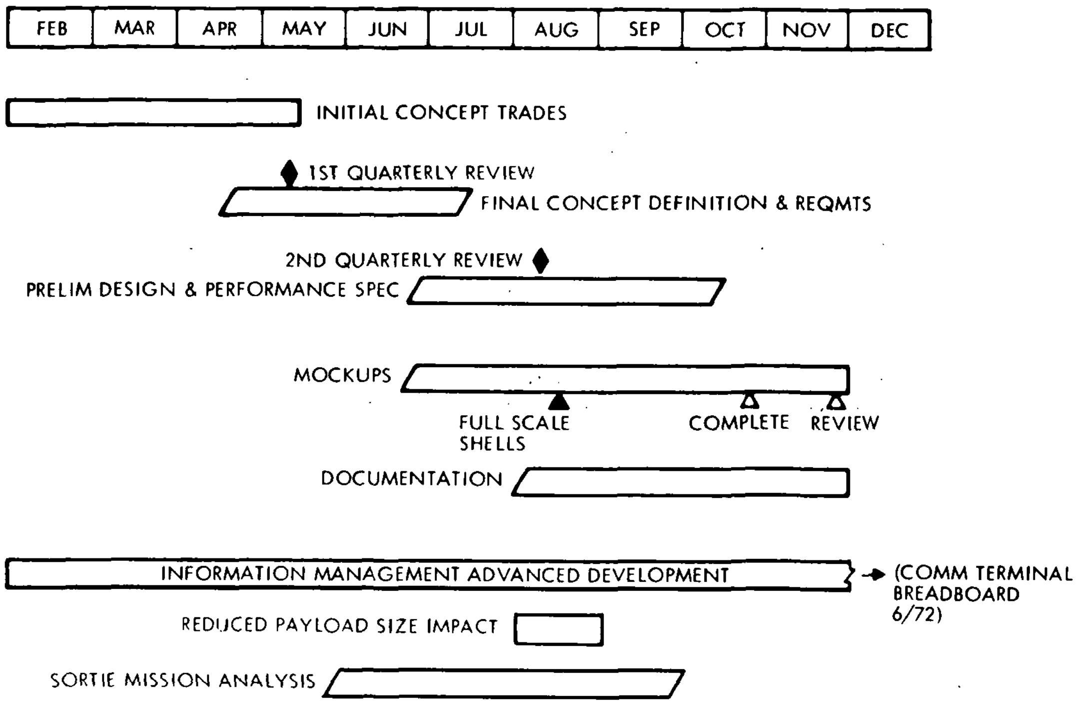


81PDS110183

The Modular Space Station Phase B study contains two major elements of activity. A 10-month conceptual and preliminary design effort is associated with the modular space station and a parallel activity associated with advanced development effort related to information management. In the former, the schedule has been arranged to provide a conceptual analysis period followed by concept selections (subsystem and system) and culminating with preliminary design and documentation. Partial mockups of crew, control, and general purpose laboratories also will be fabricated.

The information management task provides design and fabrication of a communications terminal breadboard (to be completed in July 1972) and ancillary analyses of critical elements of the total information subsystem.

MSS PHASE B SUMMARY SCHEDULE



81PDS110183

In May of 1971, the study team (MSC/NR) realigned several of the original statement of work tasks to permit investigation of the sortie mode activity that could occur between the IOC of the space shuttle and the IOC of the initial station. In addition, a study of the impact of reduced payload size was initiated in mid-July.

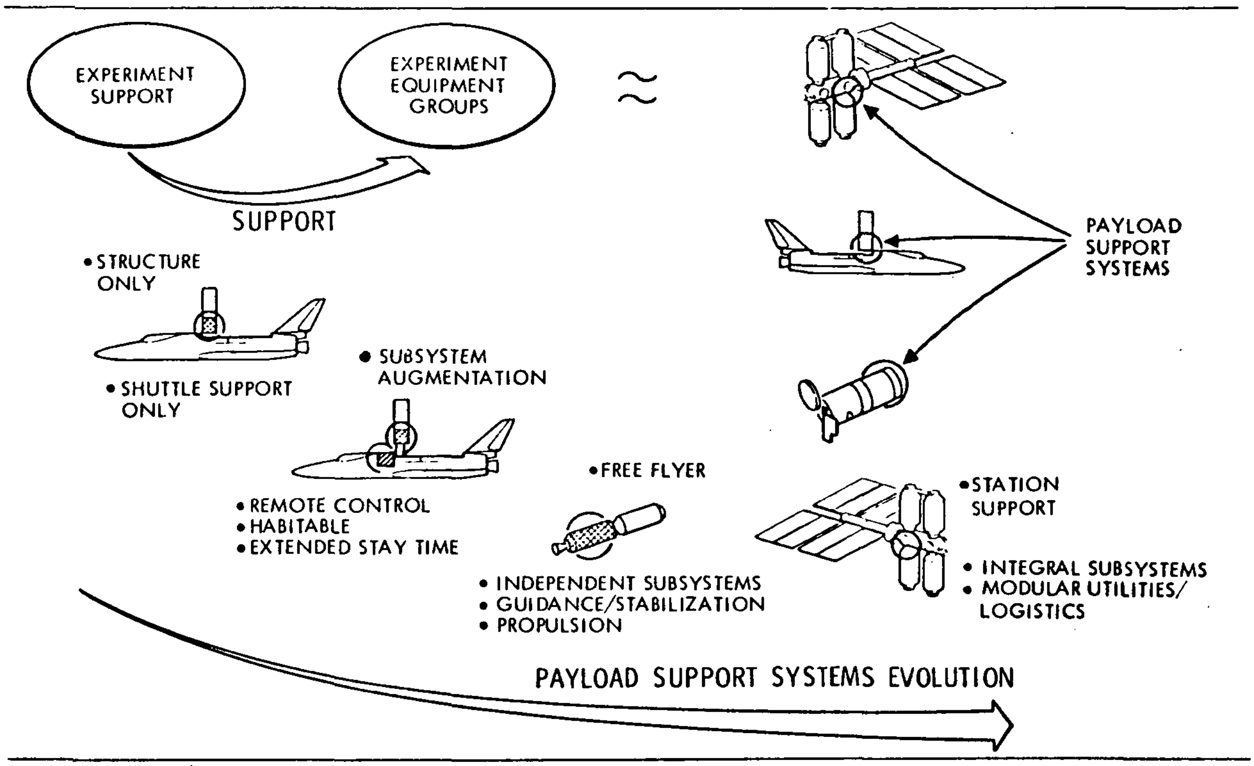
PURPOSE OF SORTIE PAYLOAD TASK

- CANDIDATE PAYLOADS - SHUTTLE TO STATION IOC GAP >3 YEARS
- DETERMINE DEGREE OF COMMONALITY (OR EVOLUTION) OF PAYLOAD SUPPORT SYSTEMS & STATION MODULES

81PDS110100

The purpose of the added sortie analysis was to identify potential candidate payloads that could operate during the 1979 to 1982 time period. These payloads would then be analyzed to determine the degree of commonality (or noncommonality) between space station modules and subsystems. This commonality, if it existed, could provide the potential for early verification of the system and subsystem concepts for the station.

EVOLUTION OF SUPPORT SYSTEMS



81PDS110184

Payload support is provided at the system level at a station docking port, a shuttle orbiter port, or a support section to a free-flying module. Payload support can evolve from a simple structural attachment to the orbiter, subsystem augmentation to the orbiter, or independent systems, and can culminate in maximized support from an orbiting space station.

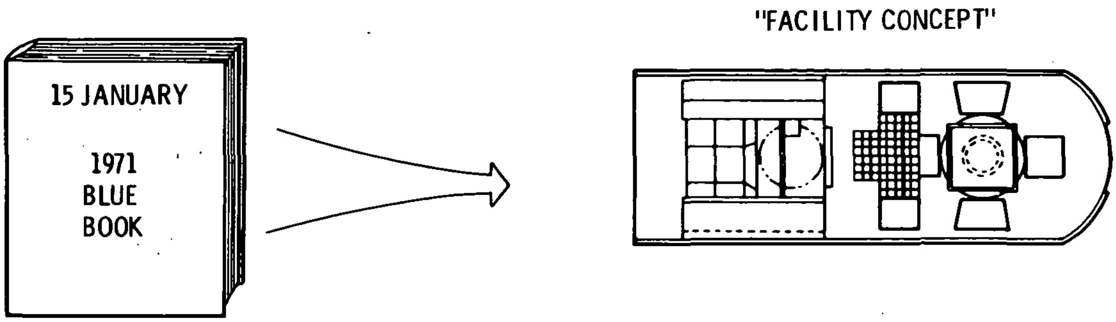
SCOPE OF CURRENT SHUTTLE PAYLOAD STUDIES

SCOPE PARAMETER	NR (MSS) SORTIE ANALYSIS	SHUTTLE ORBITAL APPLICATIONS & REQUIREMENTS	RESEARCH & APPLICATION MODULES
		SOAR	RAM
TYPE OF PAYLOADS (SOURCES)			
AEROSPACE FLEET ANALYSIS (UNMANNED SATELLITES)		●	
NASA BLUE BOOK 1971	●	●	●
SHUTTLE PAYLOAD PLANNING ACTIVITY (II)			●
OPERATIONAL TIME PERIODS			
FIRST 10 PAYLOADS		●	●
SHUTTLE TO STATIONS IOC GAP~3 YR	●		●
REFERENCE EXPT PROGRAM (1978 - 1990)			●
MISSION MODES			
SHUTTLE SUPPORTED - ATTACHED	●	●	●
SHUTTLE SUPPORTED - FREE FLYER		●	●
STATION SUPPORTED - ATTACHED			●
STATION SUPPORTED - FREE FLYER			●
PAYLOAD SUPPORT SYSTEM APPROACHES			
PALLETS		●	●
MISSION SUPPORT MODULES		●	
PRESSURIZED RAM & RSM			●
VARIOUS ACCOMMODATION CONCEPTS			●
NR SPACE STATION ELEMENT EVOLUTION	●		

81PDS110102

It was recognized at the outset that other studies of shuttle payloads were being conducted. The NR study was specifically scoped to analyze a restricted portion of the available source data and concentrated on the shuttle-to-station IOC period. The sortie missions beyond that time frame were excluded from the study because of the evolution objective described previously. In addition, this study was constrained to those sortie missions that would operate with the payload attached and considered only those payloads that could provide an evolution to the NR space station elements.

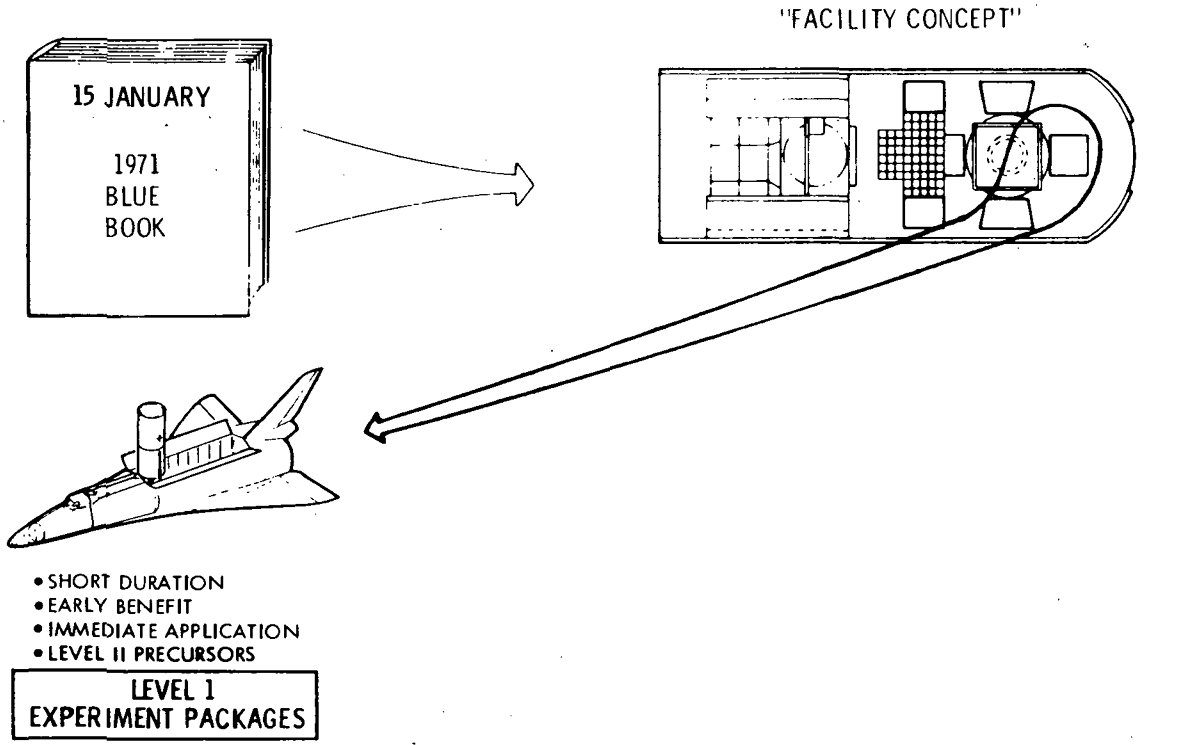
LABORATORY EVOLUTION PHILOSOPHY



71PDS108458

This evolution philosophy is derived from the approach used in the 1971 Blue Book, in which the functional program elements (FPE's) of the earlier Blue Book had been "facilitized."

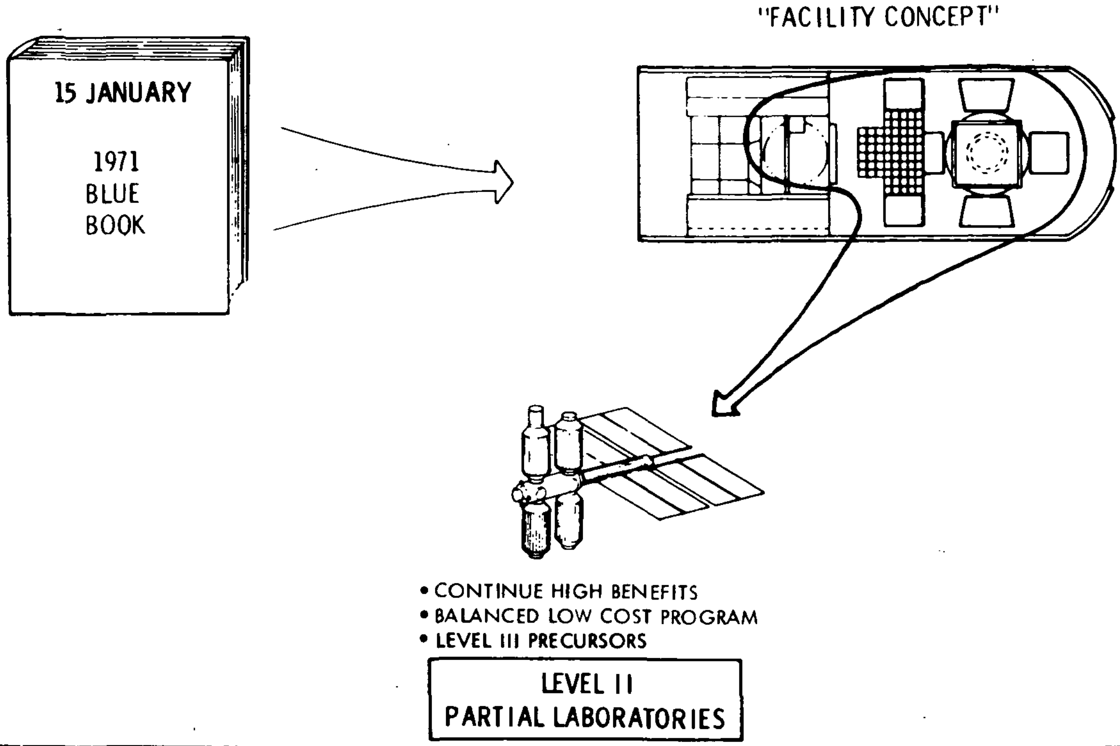
LABORATORY EVOLUTION PHILOSOPHY



71PDS108458-1

The initial step in the evolution establishes experiment packages that are fundamental portions of an eventual facility and that are (1) compatible with the sortie mission mode and (2) provide early low-cost benefits and applications. These packages (subsequently consolidated with other packages into combined payloads) were essentially precursors to the initial level of experiments on the space station.

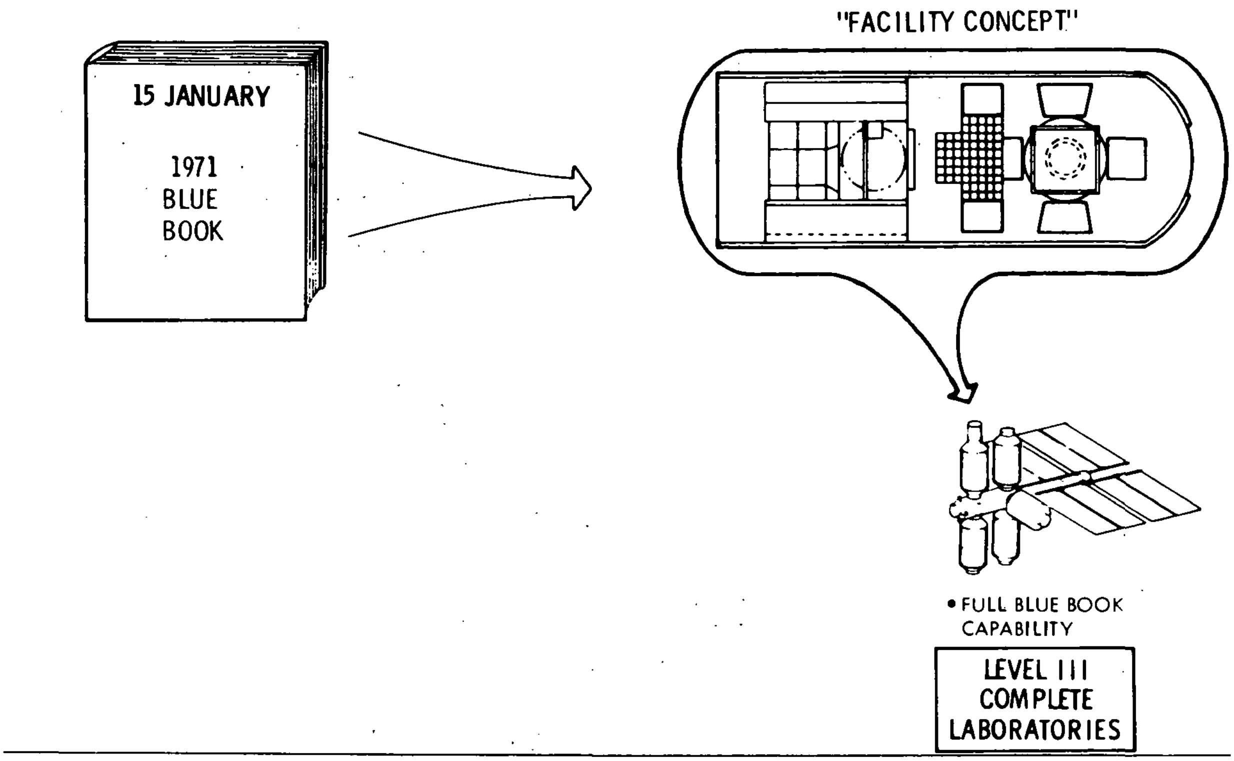
LABORATORY EVOLUTION PHILOSOPHY



71PDS108458-2

Level II adds those equipments associated with long-duration or permanent-type experiments, emphasizing a balanced but low-cost program. In general, high-cost research and scientific-oriented equipment is deferred to the final level.

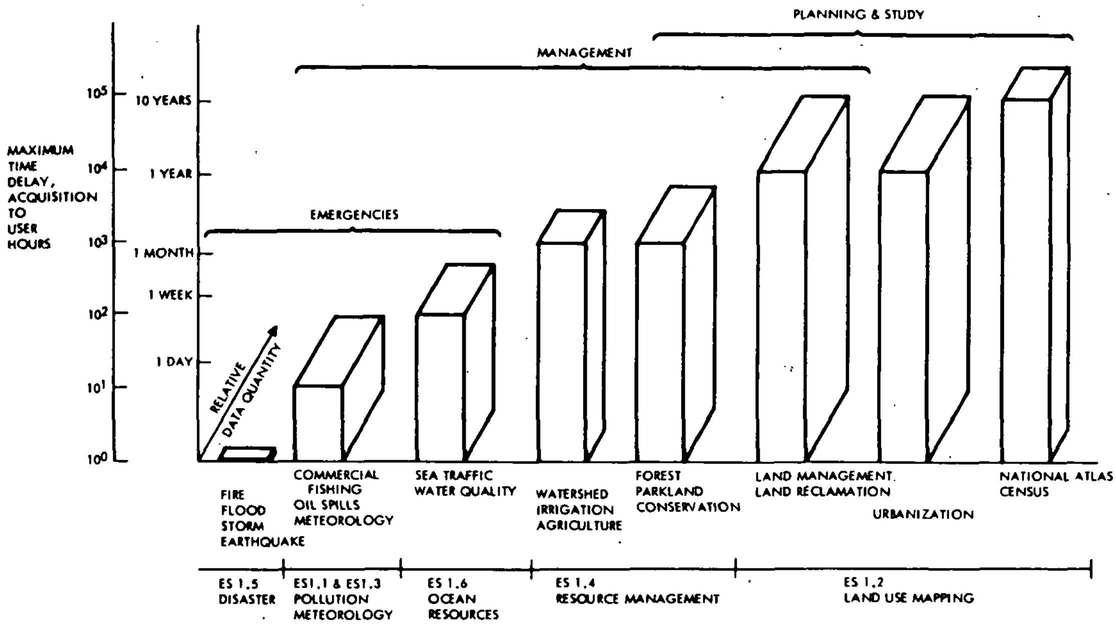
LABORATORY EVOLUTION PHILOSOPHY



71PDS108458-3

Level III consists of the total Blue Book facility.

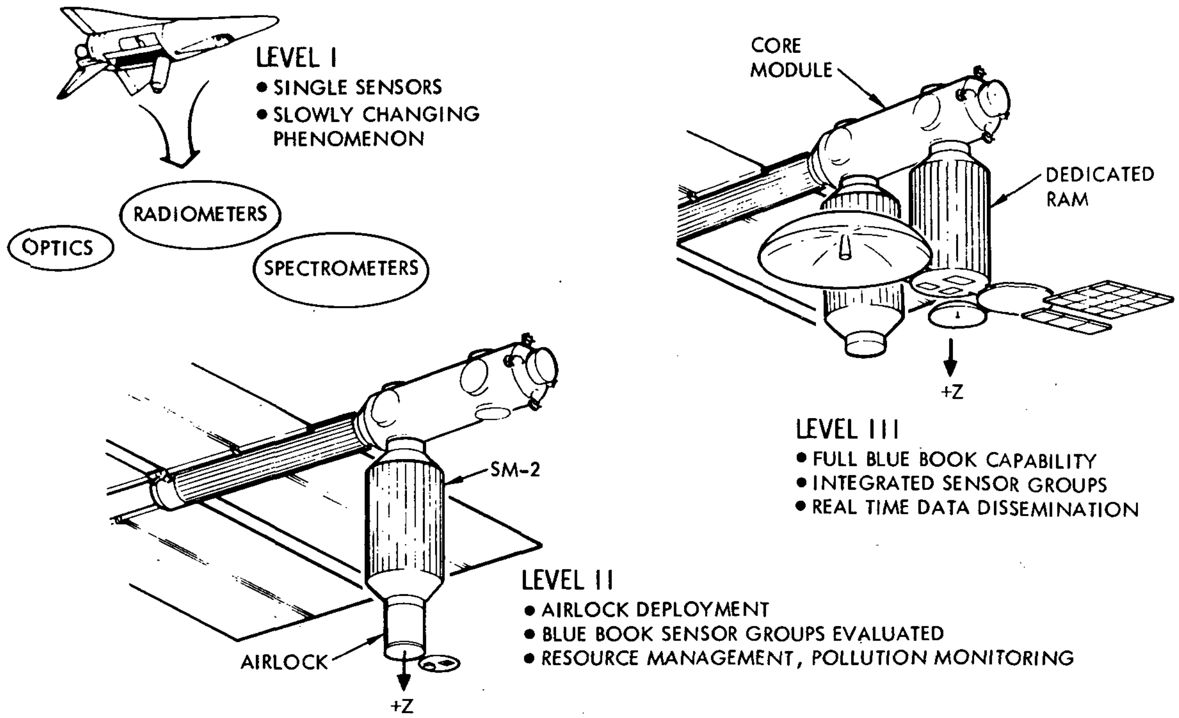
EARTH OBSERVATIONS DATA USER REQUIREMENTS



71PDS108471

A key factor in developing the evolution philosophy for the Earth Observation FPE is the consideration of the quantity of data to be acquired and the rapidity with which they must be disseminated to the users. Plotted here, for a wide range of areas of interest, is the relative maximum permissible "aging" of various types of data and their relative quantitites. Corresponding Blue Book experiments are indicated at the bottom of the chart. Inherently, systems that must disseminate data from sensor to user in near real time are significantly more complex and sophisticated than systems in which time delays in terms of months or years are permissible. Therefore, the experiments selected for Level I should be those typical of the right-hand side of the chart, and those deferred to Level II should be those typical of the left-hand side of the chart.

EARTH OBSERVATIONS LABORATORY EVOLUTION

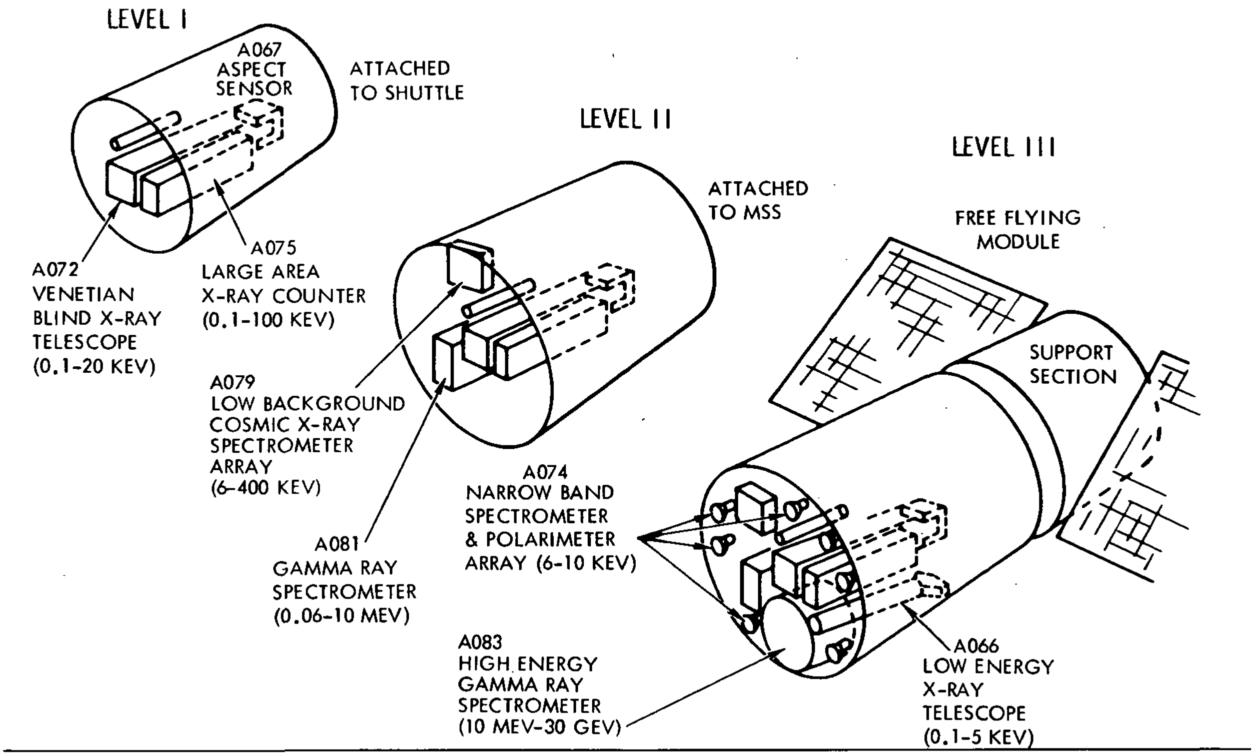


71PDS108460

Consequently, the experiments selected for earth observations Level I are those associated with slowly changing phenomena, such as land-use mapping, geology, etc. Also selected are precursor experiments such as signature research and simplified remote sensing techniques. At Level II, more sophisticated and shorter turnaround experiments are introduced such as pollution monitoring. The sensors can be deployed in groups, sequentially, through an airlock, thereby deferring the need for a dedicated RAM. At Level III, an all-up Earth Observation Facility capable of deploying all sensors simultaneously will be employed.

EVOLUTION OF HIGH-ENERGY STELLAR ASTRONOMY FACILITY

(A.5)



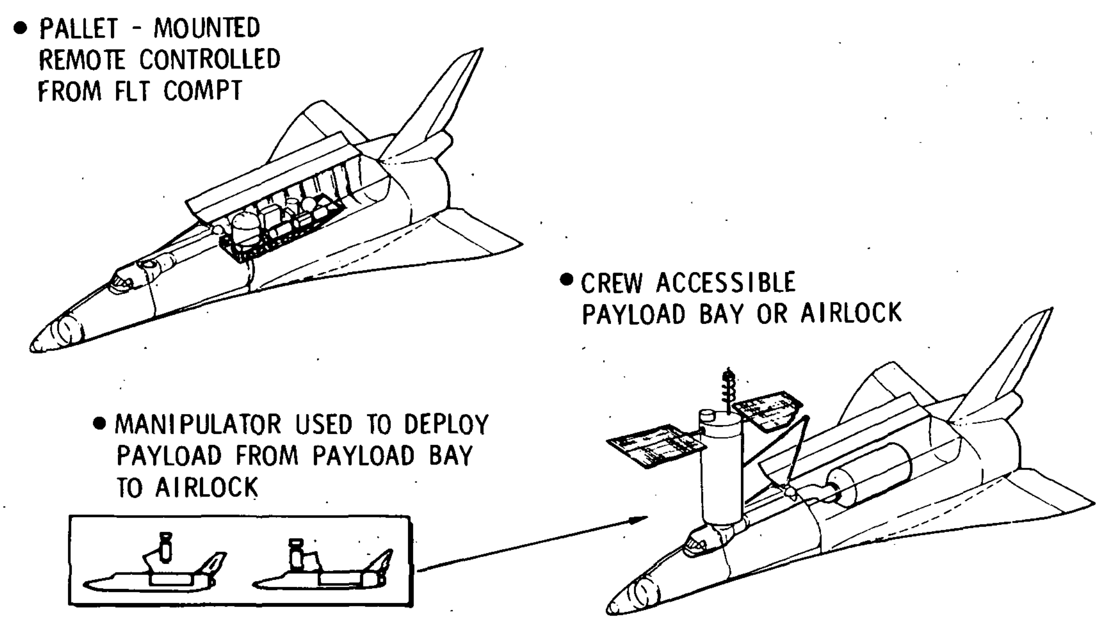
71PDS108459

Shown here is an example of the evolution philosophy applied to FPE A.5, high-energy stellar astronomy. At Level I, equipment associated with the mapping of unique strong X-ray sources has been selected. This relatively low-cost equipment requires a moderate level of stability and freedom from contamination and supports experiments of short duration. Therefore, Level I is a candidate for a shuttle attached mode.

Level II extends the range of investigation to the higher energies, adding slightly more sophisticated equipment and more stringent stability and contamination requirements. It is feasible, however, to operate Level II in a station attached mode.

Level III adds the remaining FPE A.5 equipment, extending the experiments to the low-energy sources. The extreme stability and contamination requirements of this level will very likely dictate a free-flying operating mode.

PAYLOAD LOCATION ALTERNATIVES



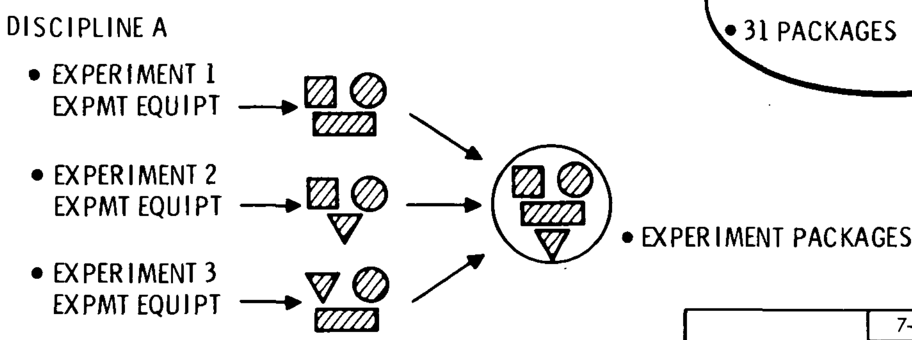
71PDS108497

The fundamental modes of accommodation provided by the shuttle orbiter are: (1) pallet-mounted without need for crew physical access and (2) payloads that require crew access or specialized environments.

SORTIE EXPERIMENT PACKAGES

LEVEL I

- 67 EXPMTS ≈ 46% BLUEBOOK
- 31 PACKAGES



ADDITIONAL PACKAGING CONSIDERATIONS:

- SIMILAR/RELATED SUPPORT REQMTS
- RELATED UNIQUE REQMTS e.g. STAB.
- TOTAL OPERATING TIME REQD

DISCIPLINE	7-DAYS EXP PKG	30-DAYS EXP PKG
ASTRONOMY		5
PHYSICS	3	3
EARTH OBSERV	2	1
COMM/NAV	1	2
MATL SCIENCE	1	
TECHNOLOGY	5	2
LIFE SCIENCES	2	4
TOTAL	14	17

81PDS108500

The 145 experiments of the 1971 Blue Book were passed through an initial screening process that considered cost, complexity, applicability to short duration, evolution potential, and basic operating time. Sixty-seven experiments passed this screening and were analyzed for commonality of equipment and related requirements such as stability and resulted in 14 packages suitable for a 7-day sortie and 17 packages adaptable to a 30-day mission.

POTENTIAL LEVEL I PAYLOADS

7-DAY SORTIE MISSION

PAYLOAD NO.	EXPERIMENT PACKAGE	INCL (DEG)	ALT (N MI)	CREW * SIZE	GROUPING RATIONALE	NO MISSIONS
1	MATERIALS SCIENCE	28-1/2°	200	2	ACCEL LIMITS	11-30
2	PLANT GROWTH CELLS & TISSUES EVA	28-1/2°	100	3	DISCIPLINE RELATED	5
3	EARTH OBS ADVANCED S/C SYSTEMS TESTS CONTAMINATION TECHNOLOGY SPACE PHYSICS	70° (550)	100-300	5	ORBIT RELATED	28
4	EARTH OBS CONTAMINATION TECHNOLOGY SPACE PHYSICS	90°	100-300	3	ORBIT RELATED	28
5	CONTAMINATION TECHNOLOGY SPACE PHYSICS	90°	300-400	2	ORBIT RELATED	3
6	PLASMA PHYSICS	55°	270	2	ORBIT/OPERATIONL MODE RELATED	2
	*EXCLUDES PILOT/COPILOT				TOTAL RANGE	77-96

81PDS110185

The packages were then combined into payloads that desired similar orbital conditions or were otherwise related. This chart and the following chart define the payloads established for the 7-day and 30-day payloads. Several of these payloads (7-day) can be readily accommodated in a pallet mode and are thus excluded from further analysis in this study, because commonality of station subsystems or modules is not evident. The crew size identified is that required as a research crew and does not include the shuttle orbiter pilot or copilot. A total of 133 to 153 missions can be identified for these payloads. The remaining effort will analyze the degree of commonality between these payloads and the station elements.

POTENTIAL LEVEL I PAYLOADS
30-DAY SORTIE MISSIONS

PAYLOAD NO.	EXPERIMENT PACKAGE	INCL (DEG)	ALT (N MI)	CREW * SIZE	GROUPING RATIONALE	NO. MISSIONS
1	MEDICAL RESEARCH BIO-SCIENCE LIFE SUPPORT MAN SYSTEMS	28-1/2	100	3	DISCIPLINE ORIENTED	10
2	SPACE PHYSICS PHYSICS & CHEM	28-1/2	200	2	DISCIPLINE ORIENTED	2
3	FLUID MGMT	28-1/2	300	2	CONTROLLED ACCELERATIONS	2
4	EARTH OBS CONTAMINATION TECHNOLOGY	70	100	2	ORBIT RELATED	15
5	X-RAY STELLAR ASTRONOMY	0	400	2	DNA	2
6	ADVANCED SOLAR ASTRONOMY	SUN SYNCH	270	2	DNA	5
7	INTERMEDIATE U-V TELESCOPE	28-1/2	270	2	DNA	4
8	HIGH ENERGY STELLAR ASTRONOMY	0	400	2	DNA	6
9	INFRA-RED ASTRONOMY	55	270	2	DNA	4
10	COSMIC RAY PHYSICS	28-1/2	200	2	DNA	7
					TOTAL RANGE	57

*EXCLUDES PILOT/COPILOT

81PDS110186

(See previous chart discussion.)

1969 TO 1971 BLUE BOOK IMPACTS

INCREASED SCOPE

EXPERIMENT HOURS ~ 88,000 TO 213,000

NEW DISCIPLINES ~ COMM & NAVIGATION, TECHNOLOGY

ALL-UP LABORATORY CONCEPT

SATISFIED BY

ACCOMMODATION INNOVATIONS
- LOWER REQUIREMENT ~ LESS COST

REQUIREMENTS INTERPRETATION

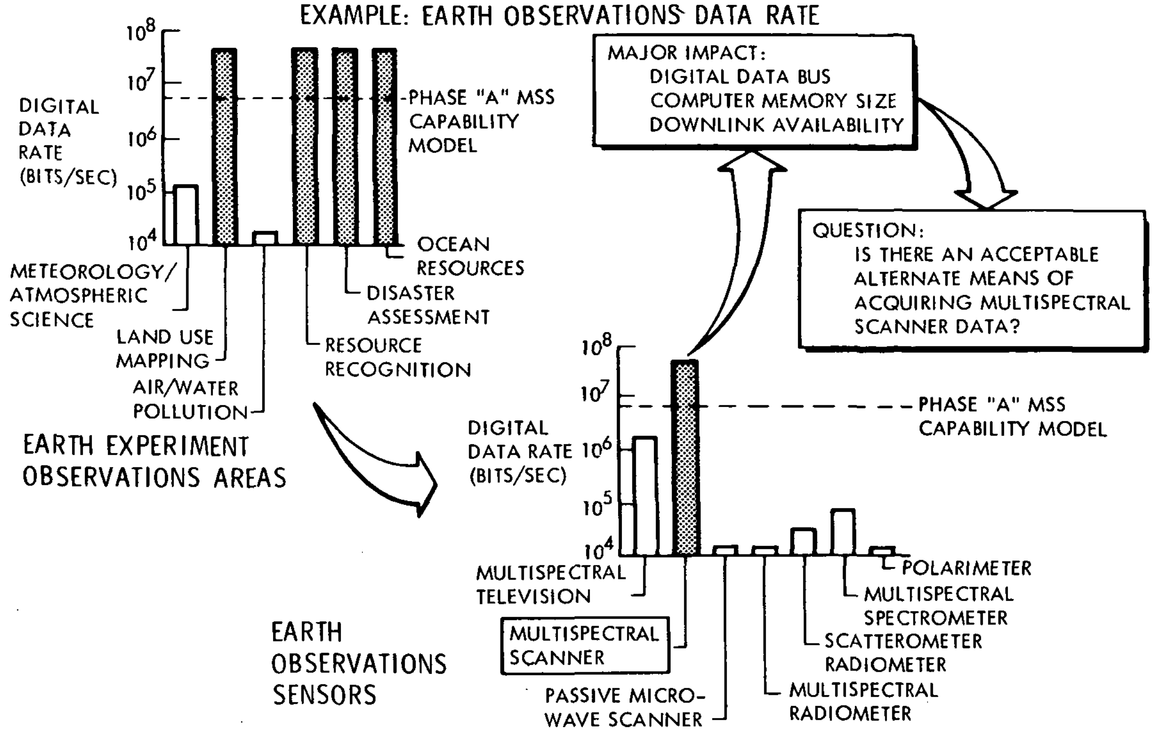
INCREASED OPERATIONAL TIME

81PDS110188

The guidelines for the Modular Space Station Phase B Extension imposed the new February 1971 Blue Book as the experiment baseline. Another guideline specified that the growth station must be equivalent in capability to that which had been based on the 1969 Blue Book. The changes in scope to be accommodated were: (1) an increase in experiment hours to meet objectives of approximately 2-1/2 times, (2) addition of a new discipline of communication and navigation, and (3) the addition of major changes in the advanced technology discipline. The 1971 Blue Book also presented an all-up laboratory concept, which was a slightly different concept from "typical experiments" in the previous 1969 Blue Book. These changes represented some sophisticated experiment hardware, but most influencing is the quantity or duration of experiment activity.

NR satisfied these requirements by creating accommodation innovations that led to lower requirements and less cost. Where experiment support requirements seemed excessive, coordination with the principal members of the Blue Book Steering Group led to improved interpretations and reduced requirements. Many of the increases in operational activities can be accommodated by allowing an increase in the operational time period for completion of the Blue Book objectives.

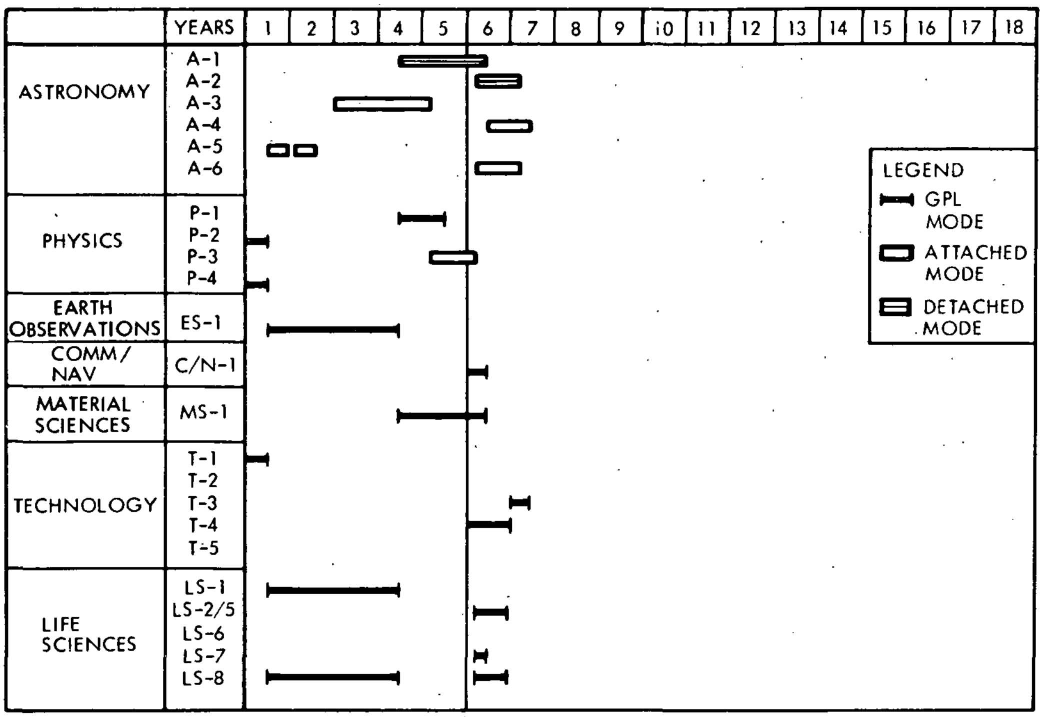
DRIVER ACCOMMODATION BY ALTERNATE IMPLEMENTATION



71PDS108446

An example of the "alternate implementation" mode of accommodation is depicted here. The driver was the high data rate of the earth observations FPE. Analysis of the individual experiments (land-use mapping and ocean resources) yielded no relief; however, further penetration revealed that in each of high-use experiments, the multispectral scanner instrument was paramount in producing the high rate of data. An implementation scheme was developed whereby the station information system was reconfigured to add a frequency multiplexer that eliminated analog to digital conversion, utilized the existing audio/video bus, provided a versatility that previously had not been available, and reduced the FPE data rate to an acceptable level.

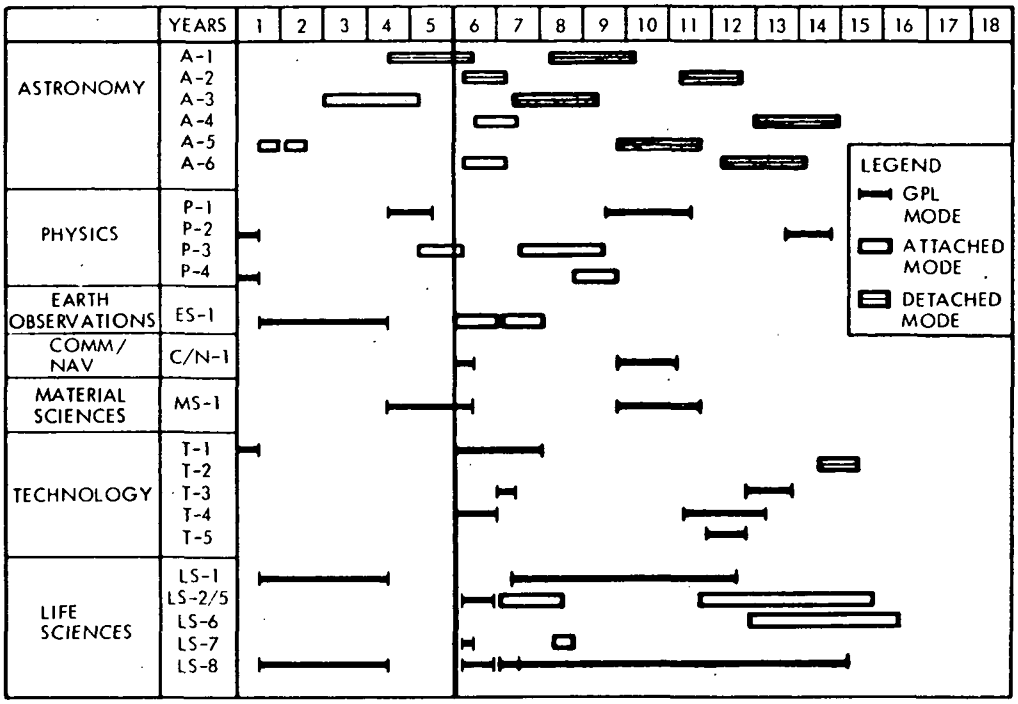
REFERENCE PROGRAM - LEVEL II
(STATION ACCOMODATIONS ONLY)



71PDS108474

Shown here is the time phasing for the Level II laboratories along with a coding indicating their mode of accommodation. The first six months are used in conducting those portions of the physics and technology FPE's assocated with determining and mapping the external environment of the station. This clears the way for initiation of critical outward looking FPE's, such as high energy stellar astronomy (A-5) and earth observations (ES-1). The vertical line at the end of year 5 indicates the IOC date for the growth station.

REFERENCE PROGRAM - LEVEL II & LEVEL III
(STATION ACCOMODATIONS ONLY)

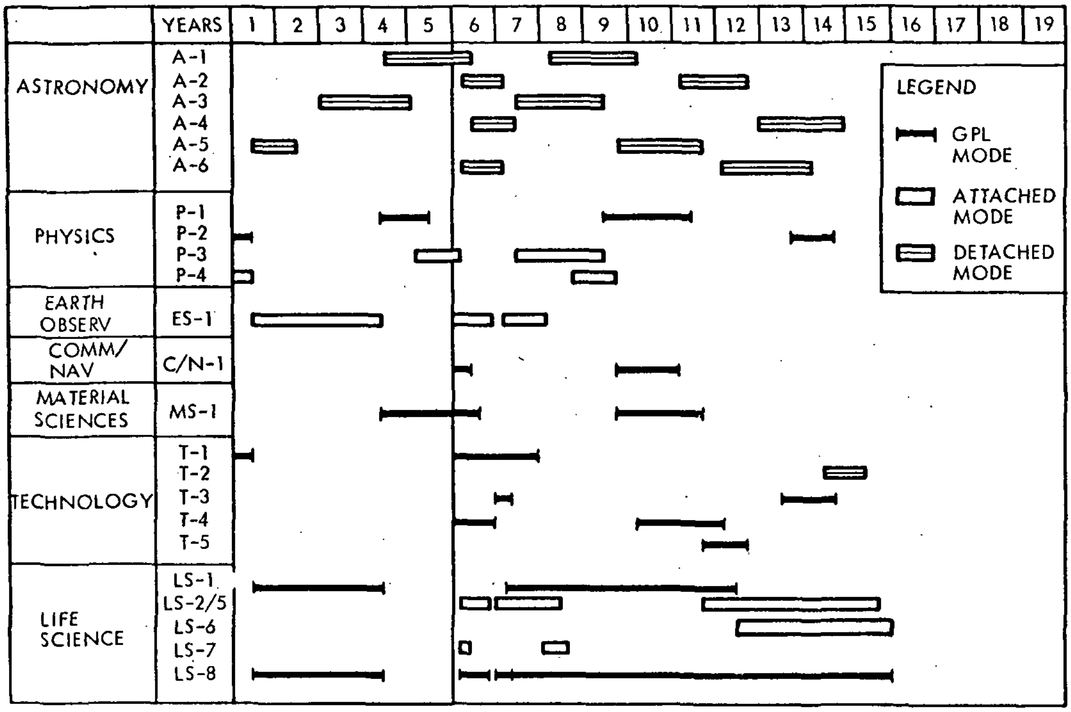


71PDS108474

This chart shows the phasing of the Level III laboratories. Several features are worthy of note. First, the sequencing of the astronomy free-flyers will permit the time sharing of one or two refurbished RAM's. Several FPE's (e.g., ES-1 and LS-2/5) evolve from a GPL mode at Level II to a dedicated attached RAM mode at Level III. Finally, the evolution philosophy results in a partial, yet balanced, experiment program for the initial station.

LEVEL III ONLY PROGRAM

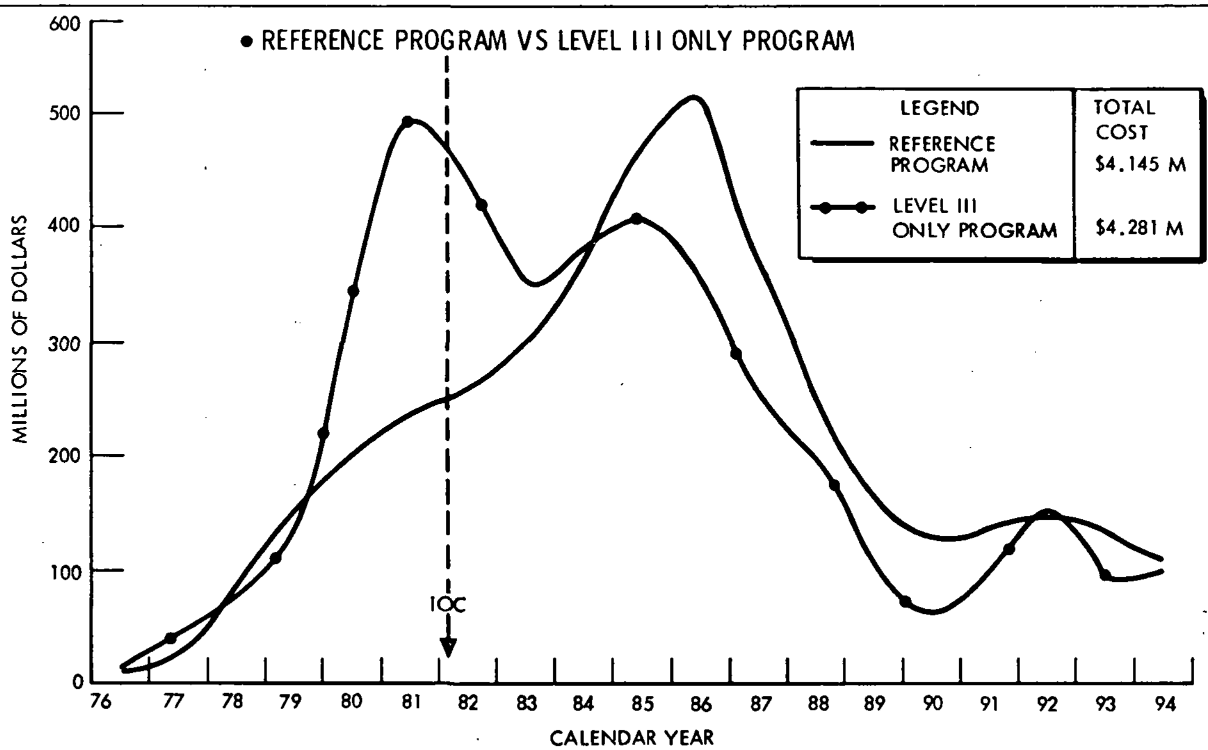
STATION ACCOMMODATION ONLY



81PDS110190

It is of interest to compare the evolutionary approach to one that goes directly to the all-up Level III laboratories. Shown here is the time phasing for such a program. To make the comparison on an equal basis, the total operating time for each FPE in this program was made equal to that shown in the reference (evolutionary) program.

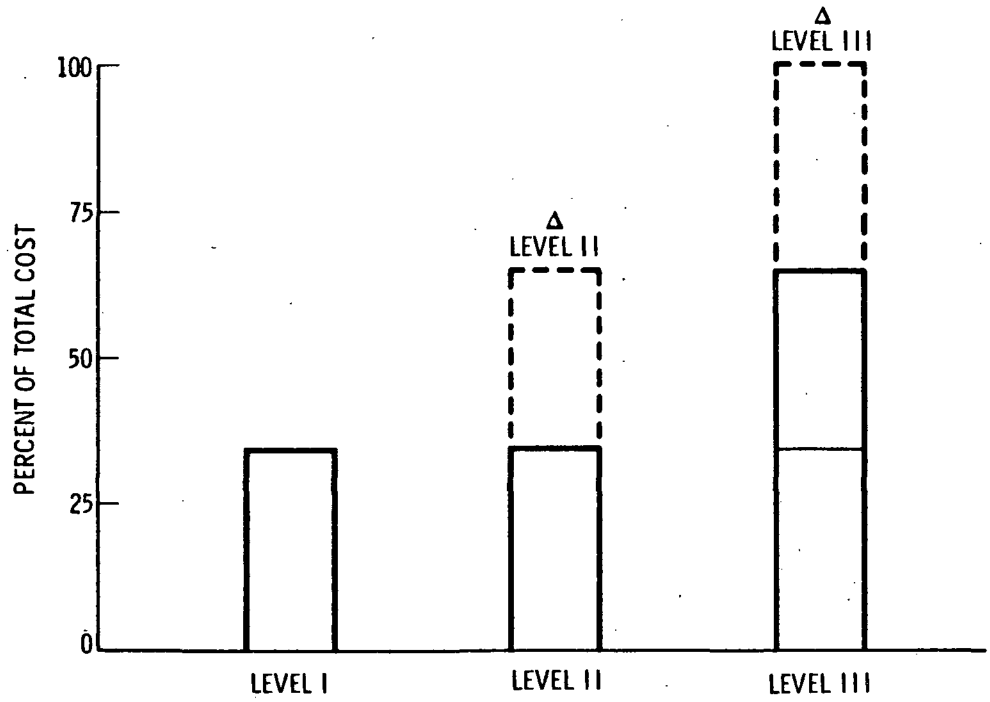
EXPERIMENT ANNUAL FUNDING COMPARISON



81PDS110191

Plotted here is the annual funding for the two approaches. Not unexpectedly, the peak funding for the reference program occurs five years later than for the Level III only program. Therefore, the evolutionary approach will result in a delay of peak annual funding for experiments beyond the funding peak for the station but not at the expense of an unbalanced program for the initial station. The latter program is $136 million greater in total cost because of the early initiation of full operational costs and the need for added support sections for free-flying modules.

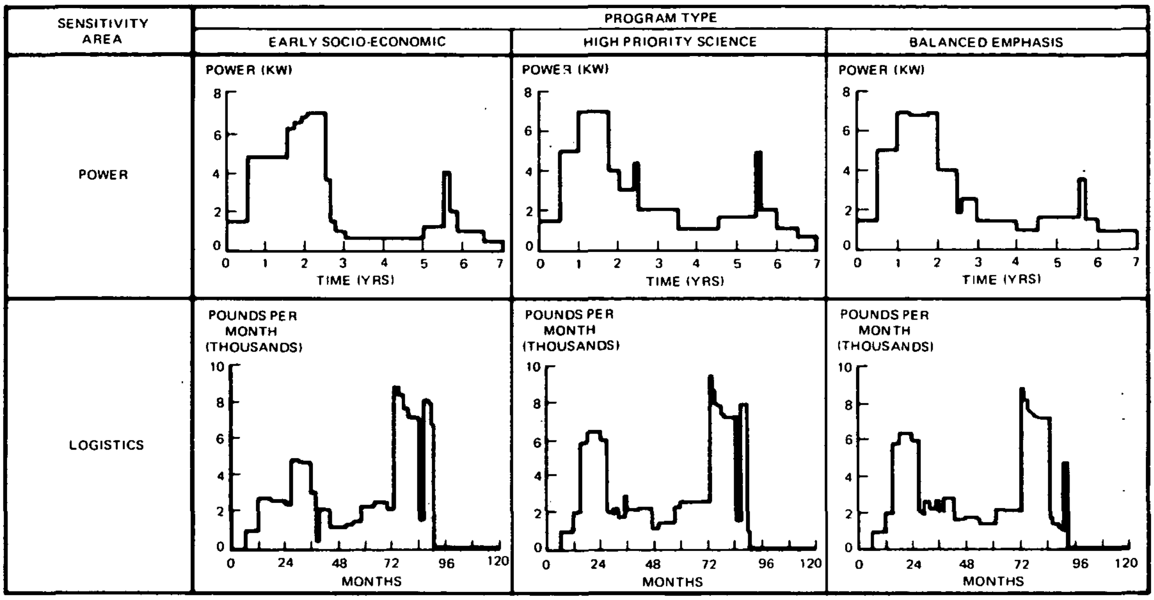
COST OF EXPERIMENT CAPABILITY LEVEL



81PDS110192

The use of experiment capability plateaus to provide an evolutionary yet worthwhile program has been demonstrated on previous charts. Use of these capability levels also provides plateaus in the funding, the effect of which is presented on this chart. The cost of the Blue Book experiments for Level I are approximately one-third of the cost of all the experiments in the Blue Book. When going to Level II, an additional expenditure of another one-third completes the experiment hardware elements at Level II. Expenditure of another one-third then will provide the total Blue Book experiments.

STATION SENSITIVITY TO EXPERIMENT PROGRAM TYPE



NO SIGNIFICANT DIFFERENCES

- DATA
- STABILITY
- CONTAMINATION
- CREW MAN HOURS

CONCLUSION : STATION DESIGN & SUBSYSTEMS RELATIVELY INSENSITIVE TO EXPERIMENT PROGRAM TYPE

81PDS110187

At the initiation of the experiment analyses, three types of programs (and phasing) were postulated: one that emphasized early socioeconomic gains, one that established the emphasis on scientific gains, and one that combined the two into a balanced emphasis. This analysis was conducted to establish the degree of sensitivity of a space station designed capability of utilities, area, and crew to a changing experiment program emphasis. This chart shows that the levels of the experiment-required accommodations are relatively constant for each of the three program types.

EXPERIMENTS SUPPORT REQUIREMENTS SUMMARY

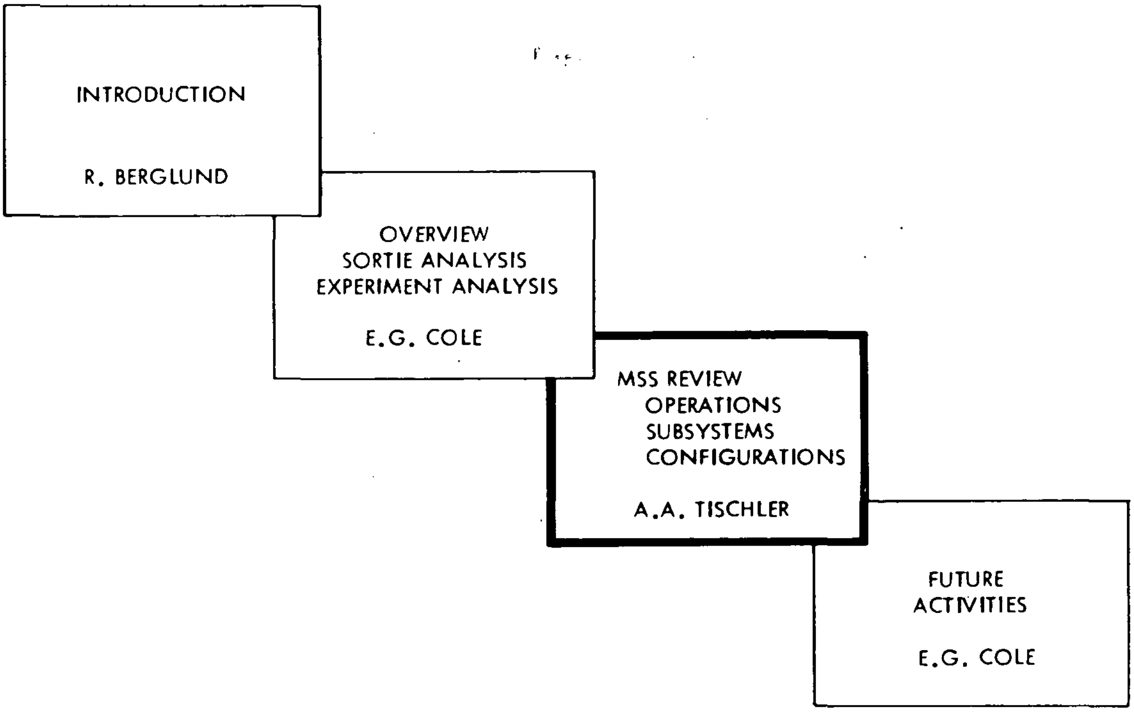
PARAMETERS	INITIAL STATION	GROWTH STATION
ELECTRICAL POWER	4.5 KW (24 HOUR AVERAGE) 7.0 KW (AVG 1 HR/12 HRS)	6.0 KW (24 HOUR AVERAGE) 9.0 KW (AVG 1 HR/12 HRS)
DATA RATES	2×10^6 BPS	2×10^6 BPS
STABILITY	.05 DEG/SEC-CONTINUOUS .01 DEG/SEC-FINE	.05 DEG/SEC-CONTINUOUS .01 DEG/SEC-FINE
POINTING	.5 DEG CONTINUOUS .1 DEG FOR 30 MIN	.5 DEG CONTINUOUS .1 DEG FOR 30 MINUTES
CREW TIME	35 MAN HOURS/DAY	80 MAN HOURS/DAY
FLOOR AREA	733 SQ FT	913 SQ FT

81PDS110090

The experiment support requirements derived from the reference phasing produced the levels of utilities, area, and crew time shown in this chart. These requirements have been used in the concept selected for the modular space station, which is described in the succeeding section of this briefing.

III. MSS REVIEW—OPERATIONS, SUBSYSTEMS, AND CONFIGURATIONS

MODULAR SPACE STATION-PHASE B
NASA HEADQUARTERS-QUARTERLY REVIEW



81PDS110193

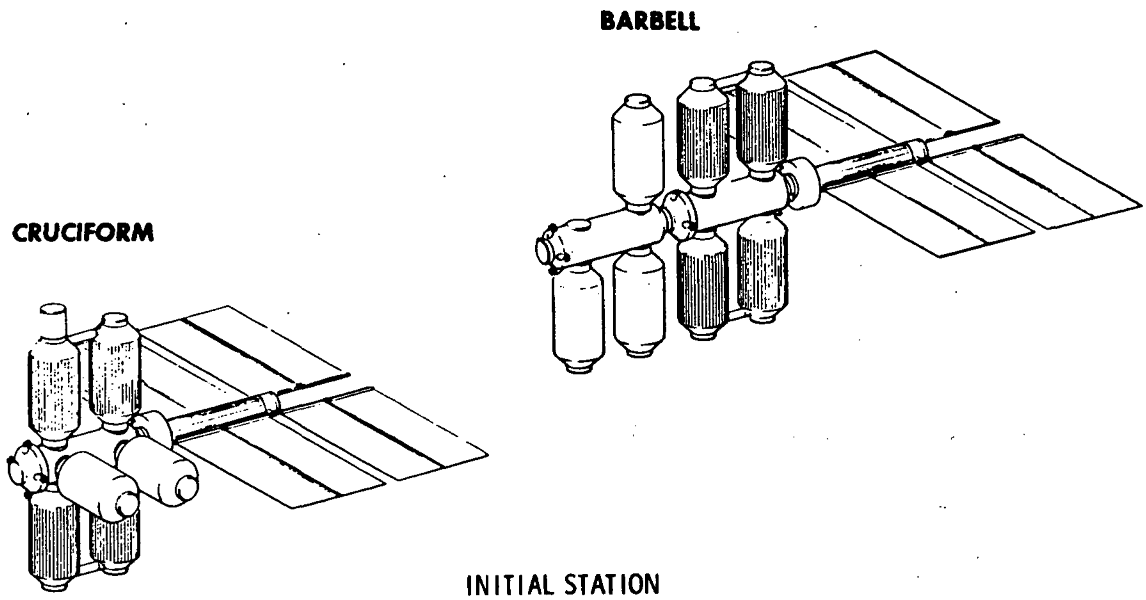
PHASE A RESULTS

- OPEN CLASS (BARBELL, CRUCIFORM, TRIMASS) MINIMIZES OPERATIONAL COMPLEXITY OF ASSEMBLY / REPLACEMENT
- OPEN CLASS REQUIRES SPECIAL DEVICE APPROACH TO MEET DUAL SHIRTSLEEVE EGRESS CRITERIA
- BARBELL / CRUCIFORM CONFIGURATIONS PROVIDE EQUIVALENT BUILD-UP OPTIONS & PLATEAU POTENTIALS
- PROGRAM COSTS / BENEFITS INSENSITIVE TO CONFIGURATION CHOICE BETWEEN BARBELL / CRUCIFORM

81PDS110194

The Phase A study of the modular space station was conducted from October 1970 through January 1971 and followed a pre-Phase A analysis conducted by NASA-MSC. Phase A activity was directed toward establishing feasible concepts for the modular space station and, through analysis of a wide range of configurations, it was determined that "open" classes such as trimass or barbell were preferred over "closed" classes such as a wheel or cube. The Phase A conceptual analysis concentrated on a cruciform configuration to establish its characteristics, because the NASA-MSC effort had adequately covered a barbell configuration at a Phase A level. For the Phase B analysis, the MSC/NR study team decided to concentrate on the barbell configuration and analyze other configurations as potential solutions to problem areas that may evolve.

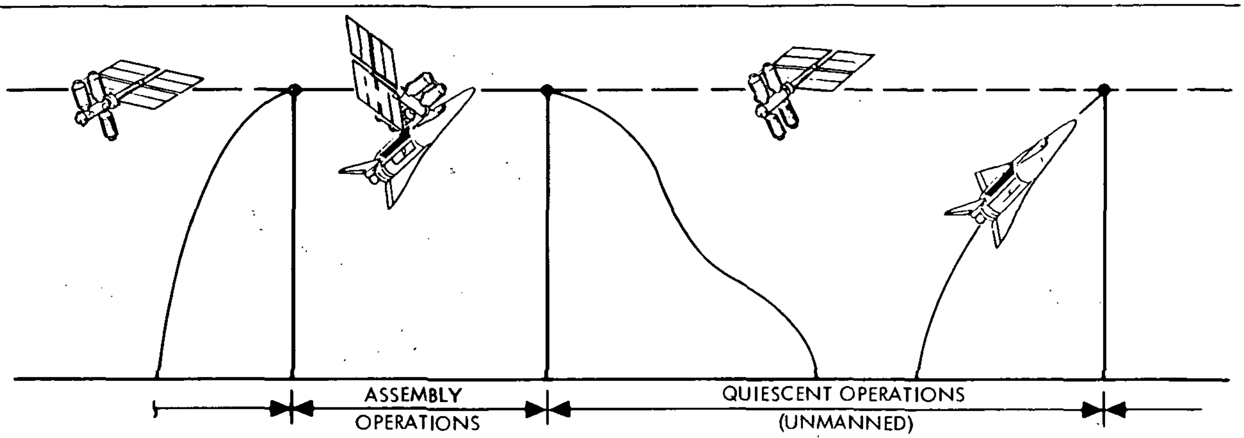
PHASE A RESULTS
CONCEPT COMPARISON



81PDS110195

The two concepts are depicted in this chart for the initial space stations. The distinguishing feature of the barbell is the "stacking" of modules in the vertical plane, while the cruciform provides attachment of modules normal to the vertical modules.

CONFIGURATION BUILDUP ISSUES



■ ASSEMBLY OPERATIONS

☐ INTERMITTENT MANNING DURING ASSEMBLY

- ROLE OF MAN
  - ACTIVATION
  - CHECKOUT
  - MAINTENANCE
- REPRESSURIZATION
- EMERGENCY CREW EGRESS
- CREW SUPPORT PROVISIONS
- ROLE OF SHUTTLE

☐ UNMANNED DURING ASSEMBLY

- EQUIPMENT RELIABILITY
- MAINTENANCE
  - REQUIREMENTS
  - APPROACH
- ACTIVATION
- CHECKOUT
- CONSUMABLES TRANSFER

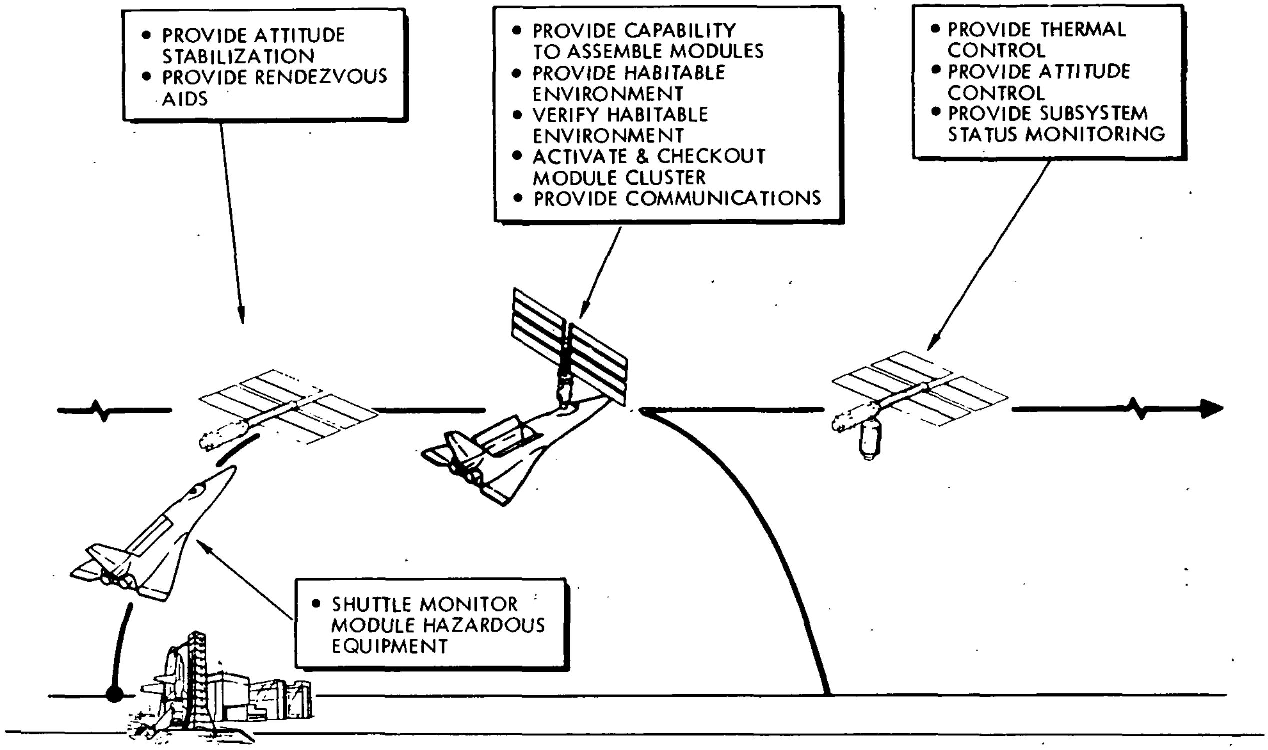
■ QUIESCENT OPERATIONS

- LEVEL OF OPERATIONS
- FAILURE CRITERIA
  - FAILURE DETECTION
  - REDUNDANCY
  - REQUIREMENTS
- CONSUMABLE REQUIREMENTS

4PDS108163

The assembly period of the modular space station has been constrained by a guideline that permits only one shuttle orbiter flight over a 30-day period. This constraint leads to periods of unmanned operation of "piece parts" of a station which desires to be designed for manned operation as an entity. The issues of assembly and the role of man in that assembly activity are compounded by the issues of the unmanned period which desires dormancy or quiescence to minimize the effects on the manned configuration.

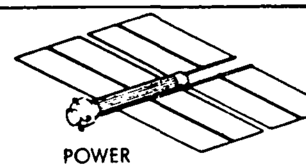
FUNCTIONAL REQUIREMENTS DRIVERS DURING BUILDUP



71PDS110035

The functions required during the various phases of buildup impose unique demands on the vehicle design. The orbiting cluster must have the capability for attitude stabilization both autonomously and by remote command to permit shuttle docking. Assurance of a habitable environment to permit checkout and activation of each added module is necessary. Following solar array deployment, continuous attitude control and thermal control of the cluster must be maintained autonomously by the orbiting cluster.

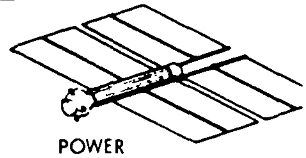
INITIAL LAUNCH ALTERNATIVES

CONSIDERATION	 CORE	 POWER
OPERATIONAL MODE	PASSIVE ATTITUDE CONTROL (GRAVITY GRADIENT)	ACTIVE ATTITUDE CONTROL (SOLAR ARRAY POINTING)
LEVEL OF INITIAL ACTIVATION	MINIMUM ACTIVATION PARTIAL DEACTIVATION PRIOR TO SHUTTLE RETURN	REQUIRES ACTIVATION OF MAJOR ASSEMBLIES
SUBSYSTEM SCARS	EPS, G&C, RCS - NO MAJOR SCARS ECLSS - POTENTIALLY ACTIVE THERMAL CONTROL ISS - "WAKE-UP" RECEIVER & BUILDUP COMM	EPS - PRIMARY BUSSES - EMERGENCY STORAGE G&C - TWO CONCEPTS OR REDUNDANT EQUIPMENT RCS - TWO ADDED QUADS ECLSS - ACTIVE THERMAL LOOPS RADIATORS ATMOSPHERIC CONTROL ISS - DPA
WEIGHT SENSITIVITY	NO SINGLE MAJOR ASSEMBLY DRIVER	SINGLE MAJOR ASSEMBLY DRIVER (SOLAR ARRAY)

81PDS110196

The initial module to be delivered to orbit preferably would have the minimum amount of scar equipment over and above that required for normal operations. It can be seen that, although the power module provides early delivery of abundant power, many additional functions must be added to the module to support that power source. The core module alternative permits use of the normally installed secondary power source and requires minimal support functions.

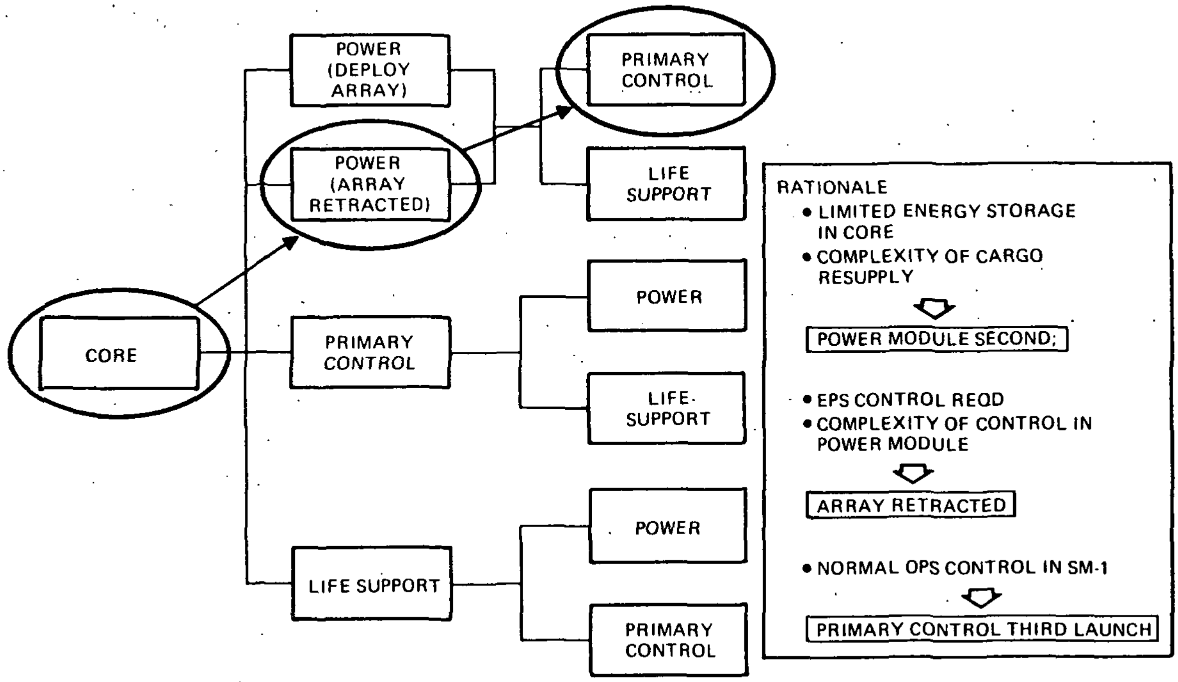
INITIAL LAUNCH ALTERNATIVES

CONSIDERATION	 CORE	 POWER
OPERATIONAL MODE	PASSIVE ATTITUDE CONTROL (GRAVITY GRADIENT)	ACTIVE ATTITUDE CONTROL (SOLAR ARRAY POINTING)
LEVEL OF INITIAL ACTIVATION	MINIMUM ACTIVATION PARTIAL DEACTIVATION PRIOR TO SHUTTLE RETURN	REQUIRES ACTIVATION OF MAJOR ASSEMBLIES
SUBSYSTEM SCARS	EPS, G&C, RCS - NO MAJOR SCARS ECLSS - POTENTIALLY ACTIVE THERMAL CONTROL ISS - "WAKE-UP" RECEIVER & BUILDUP COMM	EPS - PRIMARY BUSSES - EMERGENCY STORAGE G&C - TWO CONCEPTS OR REDUNDANT EQUIPMENT RCS - TWO ADDED QUADS ECLSS - ACTIVE THERMAL LOOPS RADIATORS ATMOSPHERIC CONTROL ISS - DPA
WEIGHT SENSITIVITY	NO SINGLE MAJOR ASSEMBLY DRIVER	SINGLE MAJOR ASSEMBLY DRIVER (SOLAR ARRAY)
	SELECTED	REJECTED TOO COMPLEX!!

81PDS110196-1

The core module has been selected for initial launch.

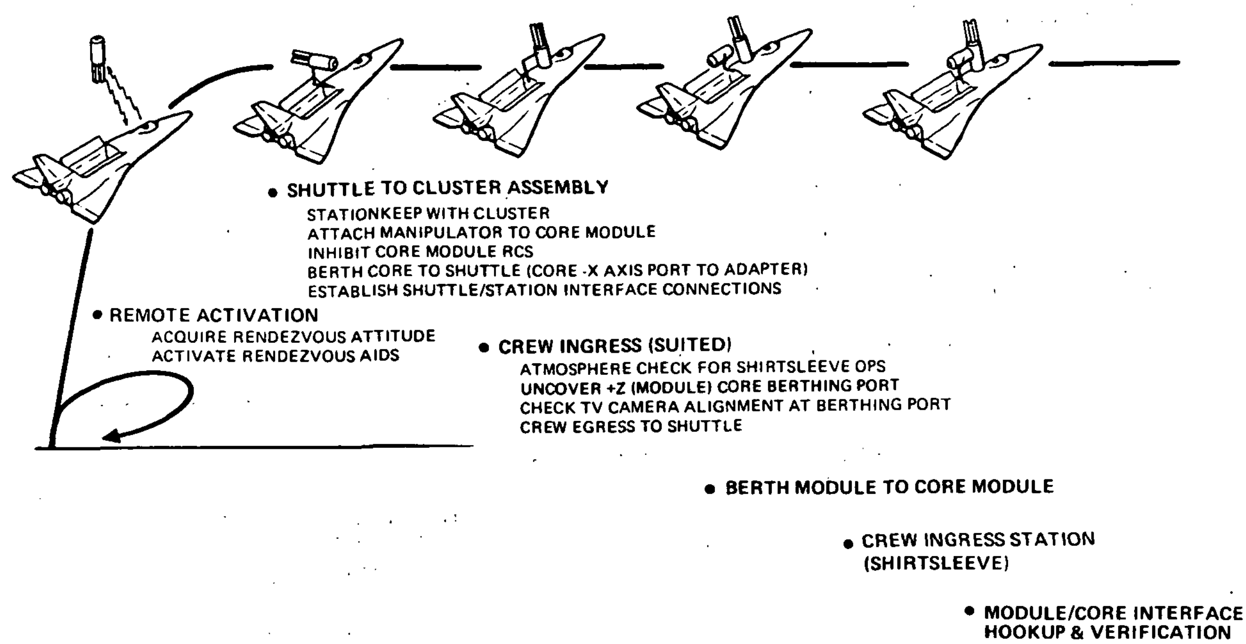
SUBSEQUENT MODULE BUILDUP SELECTION



81PDS1100 97

The delivery of subsequent modules follows a similar logic in limiting scar equipment. The power module was chosen for the second launch because of its limited need for added support particularly with the arrays retained in a retracted condition. The third launch provides a full information subsystem capability permitting array deployment, attitude control, and heat rejection capability.

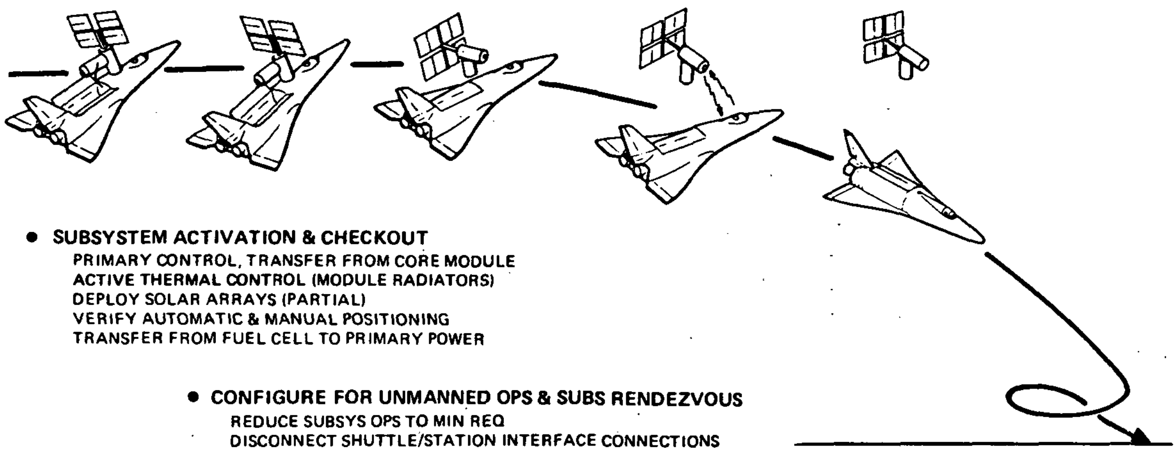
TYPICAL DELIVERY OPERATIONS SEQUENCE



81PDS110197

The activities associated with the third module delivery, assembly crew ingress, and interface hookup requires approximately 1-1/2 days from the time of launch (assuming an 8-hour rendezvous time). Two members of the shuttle 4-man crew are used for all assembly activities.

TYPICAL DELIVERY OPERATIONS SEQUENCE (CONT)

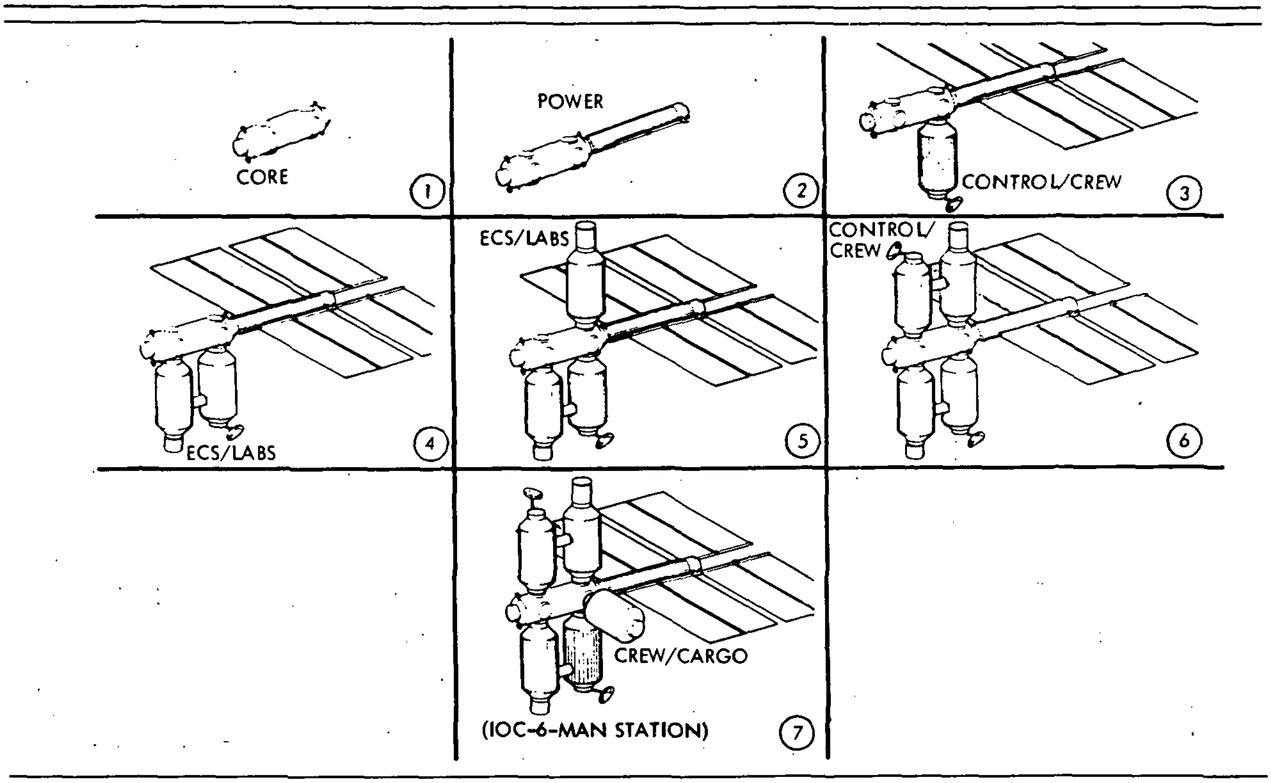


- SUBSYSTEM ACTIVATION & CHECKOUT
  - PRIMARY CONTROL, TRANSFER FROM CORE MODULE
  - ACTIVE THERMAL CONTROL (MODULE RADIATORS)
  - DEPLOY SOLAR ARRAYS (PARTIAL)
  - VERIFY AUTOMATIC & MANUAL POSITIONING
  - TRANSFER FROM FUEL CELL TO PRIMARY POWER
- CONFIGURE FOR UNMANNED OPS & SUBS RENDEZVOUS
  - REDUCE SUBSYS OPS TO MIN REQ
  - DISCONNECT SHUTTLE/STATION INTERFACE CONNECTIONS
  - CREW EGRESS TO SHUTTLE
- ORIENT SHUTTLE/STATION FOR SEPARATION
  - SHUTTLE/STATION SEPARATION
- ACTIVATE STATION RCS TO DAMP SEP TRANSIENTS & TO MAINTAIN ATTITUDE CONTROL
- DEACTIVATE FOR QUIESCENT OPERATIONS
- QUIESCENT (MINIMUM) STATION OPERATIONS

81PDS110198

The remaining activities of subsystem activation, checkout, and preparation for shuttle departure require an additional 3-1/2 days.

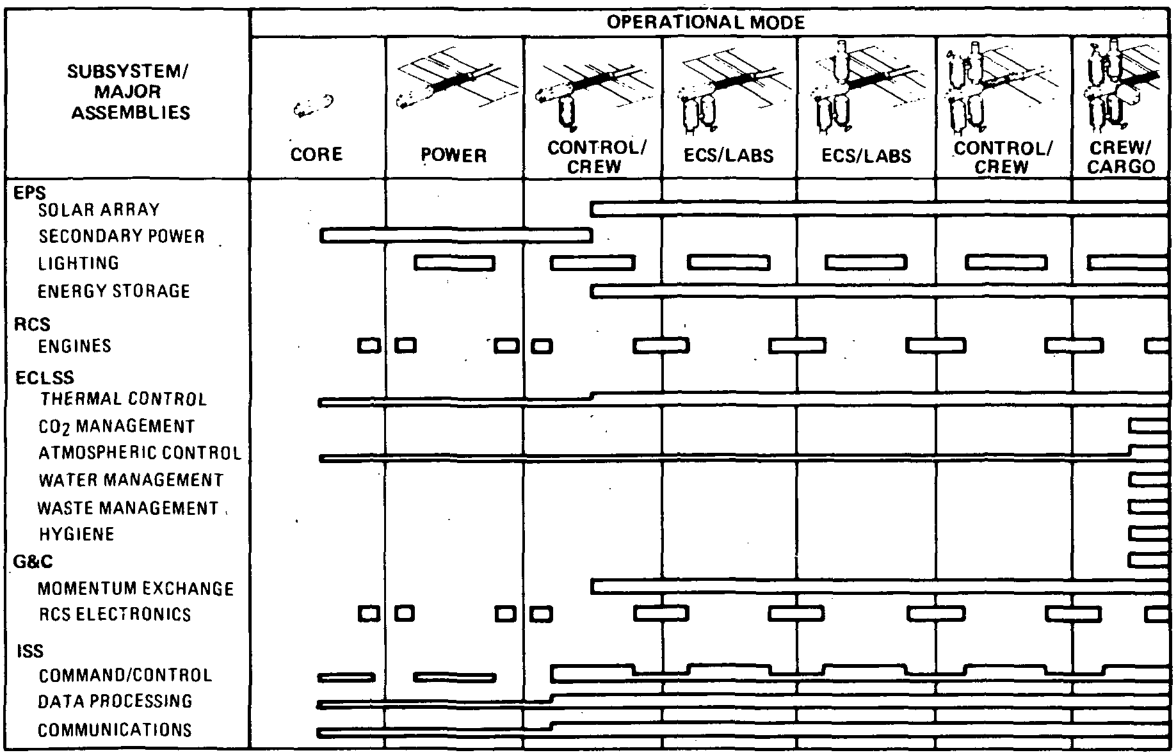
BUILDUP SEQUENCE-INITIAL MSS



81PDS110040

The resultant buildup to IOC is summarized on this chart. A potential early manning plateau exists at Step 4, and the option exists to deliver the Step 5 ECS/laboratories module at Step 4 rather than as shown.

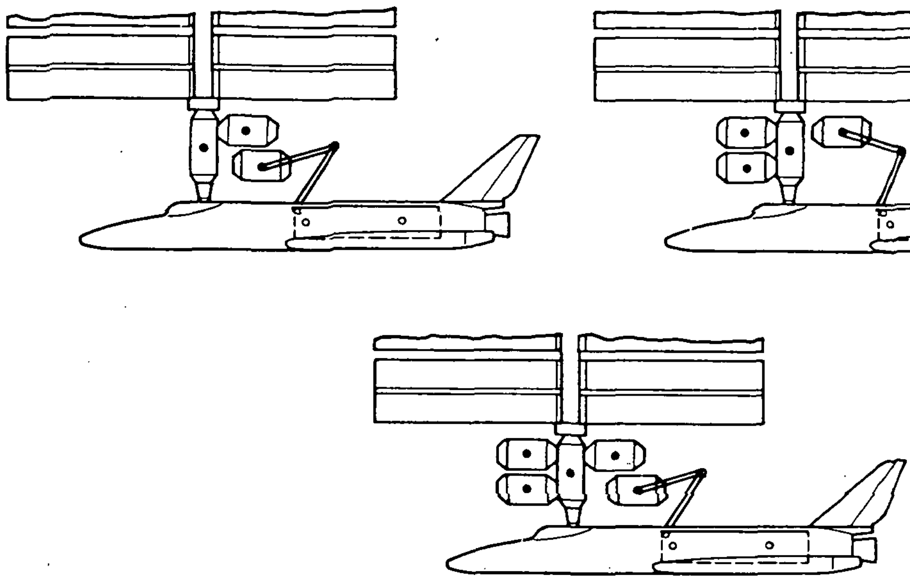
ASSEMBLY ACTIVATION & CHECKOUT REQUIREMENTS



81PDS110095

The level of activation during each stage of buildup has been limited to that required for buildup continuation. It will be noted that such functions as CO_2 management are not activated until buildup is complete and the continuous manned operations are initiated. Reaction control system (RCS) usage is limited in the first two deliveries to that required for docking stabilization. Subsequent quiescent usage of the RCS is required for orbit makeup, attitude control, etc.

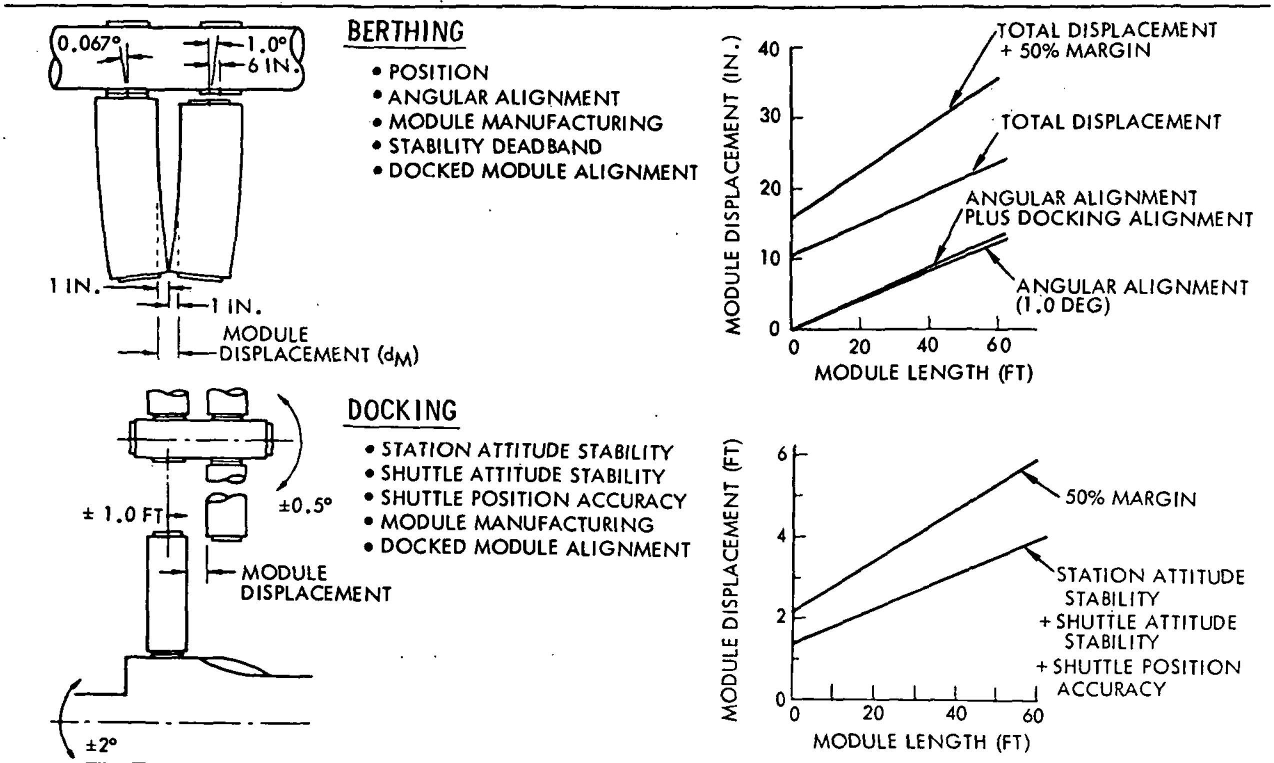
ASSEMBLY APPROACH



81PDS110199

The analyses conducted during this study rejected the installation of a manipulator on the space station and utilized the shuttle orbiter manipulation capability. Berthing the orbiter to the station (-X berthing port) provides a stable base for subsequent manipulation of modules into position.

ASSEMBLY ALIGNMENT ERRORS



81PDS110200

The potential operational mode of direct docking of modules by a shuttle orbiter translation maneuver was investigated. The alignment errors in berthing a 40-foot module dictate a 30-inch spacing between modules, whereas the spacing requirement increases to 5 feet for the direct docking mode.

ASSEMBLY MODE SELECTION

CONSIDERATIONS	IMPACT OF MODE SELECTION	
	BERTHING	DOCKING
CHANGE IN MODE	NOT POSSIBLE	WILL ACCOMMODATE EITHER
MANIPULATOR DESIGN	REACH DEPENDENT	INDEPENDENT
CORE MODULE PENALTY	NONE	(A) 3-FOOT LENGTH (5 FOOT SPACING)
COMMON MODULE PENALTY	NONE	ACTIVE PORT WITH ATTENUATION
SHUTTLE ADAPTER	SIZED TO SHUTTLE RQMTS	SIZED TO MODULE LENGTH DELTAS

CONCLUSIONS

- SELECTED 5 FOOT SPACING BUT RETAINED BERTHING MODE AS DESIGN POINT
- SYSTEM/CONFIGURATION COMPATIBLE WITH DIRECT DOCKING.

81PDS110201

Although the berthing mode has been selected for assembly operations, the spacing of modules has been established at 5 feet to permit the direct docking option to be exercised. Selection of the direct docking option at a later design phase would require the addition of attenuation mechanisms in the station modules.

MSS THERMAL CONTROL CONCLUSIONS

REJECTED CONCEPT	MAJOR ADVANTAGES	REJECTION RATIONALE
DEPLOYABLE RADIATORS	FLIGHT MODE INSENSITIVE SINGLE COOLANT LOOP REDUCED RADIATOR AREA COATING DEGRADATION INSENSITIVE	NO CONVENIENT LOCATION OPERATIONAL INTERFERENCE
HEAT PIPE	HIGH RELIABILITY LOWEST POWER NO NOISE	DEVELOPMENT/COST RISK IMPACTS ALL HARDWARE DESIGN REQUIRES INDEPENDENT TC
HYBRID	REDUCED METEOROID PUNCTURE SENSITIVITY	DUAL DEVELOPMENTS ACTIVE LOOPS + HEAT PIPES SAME CONTROL COMPLEXITY AS ACTIVE LOOP
SINGLE LOOP	LOWEST COST REDUCED MAINTENANCE	HIGH PUMPING POWER COOLANT SELECTION PROBLEMS ECLSS COMPATIBILITY PROBLEMS
INDEPENDENT THERMAL CONTROL	SIMPLE MODULE INTERFACE SIMPLIFIED GROUND TEST	HIGHEST PUMPING POWER HEAT LOAD RESTRICTIONS INSUFFICIENT REJECTION CAPABILITY
SELECTION	CENTRAL ACTIVE THERMAL CONTROL DUAL (H_2O & FREON 21) LOOPS BODY MOUNTED RADIATORS	

71PDS108544

Eighteen candidate thermal control concepts were analyzed during the study. These candidates covered the range of passive systems (heat pipes) and passive/active systems (heat pipe external, active loop internal) as well as fully active systems (independent for each module or centralized single loops or dual loops). Although many advantages can be realized from all of the candidates, the overriding criteria of minimum development, low cost, and relative simplicity narrowed the choices down to the selected approach of centralized dual coolant loop utilizing water internally and freon in external body-mounted radiators.

INTEGRATED SUBSYSTEM TECHNICAL TRADE SUMMARY

SUBSYSTEM	INDEPENDENT TRADE-OFF RESULTS
RCS	• CRYOS IN CARGO MODULES • RESISTOJET WITH N_2H_4 PACKAGES • CENTRAL N_2H_4 IN CARGO MODULE • ELECTROLYSIS WITH SHARED DEVELOPMENTS
EPS	• REGENERATIVE FUEL CELLS WITH SHARED ELECTROLYSIS DEVELOPMENT
ECLSS	• LiOH OPEN O_2 & NO ELECTROLYSIS • H_2 DEPOLARIZER WITH ELECTROLYSIS • SABATIER CLOSE O_2 CYCLE • CLOSED H_2O CYCLE

REMAINING INTEGRATED CONCEPT OPTIONS			
OPTION NO.	RCS	ETC/LSS	EPS
1-1	CRYO H_2-O_2 STA & CM	CLOSED O_2 H_2 DEPOLAR	REGEN FC
2-2	CRYO H_2-O_2 CARGO MOD	SAME	SAME
3-8	CRYO H_2-O_2 CARGO MOD	OPEN O_2 LiOH	NiCd BATT
5-3	N_2H_4 CARGO MOD	OPEN O_2 LiOH	NiCd BATT
6-1	N_2H_4 CARGO MOD	CLOSED O_2 N_2H_4 DISS H_2 DEPOLAR	REGEN FC
6-3	N_2H_4 CARGO MOD	OPEN O_2 H_2 DEPOLAR	REGEN FC
6-4	N_2H_4 PKG RESISTOJET	OPEN O_2 H_2 DEPOLAR	REGEN FC
8	ELECTROLYSIS	CLOSED O_2 H_2 DEPOLAR	REGEN FC
11-2	ELECTROLYSIS	OPEN O_2 H_2 DEPOLAR	REGEN FC

81PDS110099

Forty-one candidate concepts were identified for investigation as integrated subsystems for the reaction control system (RCS), environmental control and life support system (ECLSS), and electrical power system (EPS). Analyses conducted independently within each subsystem reduced this matrix to nine concepts, which were ranked according to development and initial 5-year operating costs. The nine candidates included (1) cryogenic options with closed or open O_2 functions and paired with batteries or fuel cells, (2) hydrazine concepts with options similar to those in item 1, and (3) water electrolysis options with open or closed O_2 and regenerative fuel cells. The lowest concepts were 11-2, 8, and 6-4.

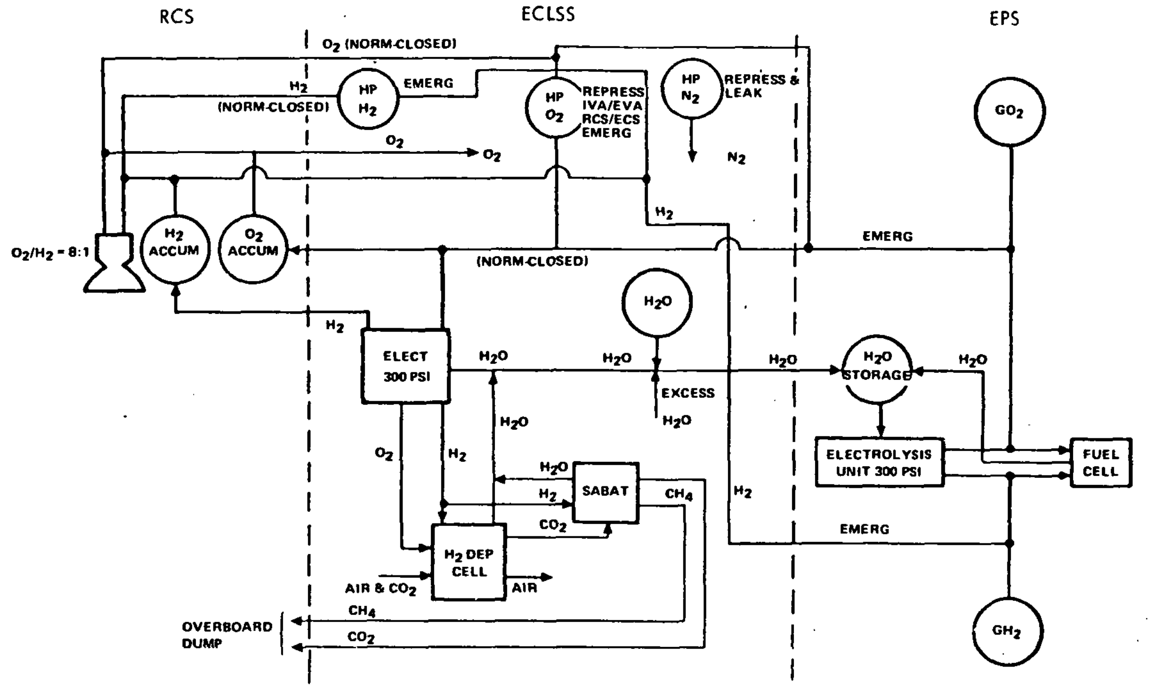
LOW COST CONCEPT COMPARISONS

CONCEPT	11-2	8	6-4
CONCEPT DESCRIPTION	RCS - ELECTROLYSIS NO RESISTOJETS	→ →	RCS - N_2H_4 PACKAGES H_2O RESISTOJETS
	EPS - REGEN FUEL CELLS	→	→
	ECLSS - OPEN O_2 H_2 DEPOLARIZER ELECTROLYSIS HP N_2 REPRES	ECLSS - CLOSED O_2 → → →	ECLSS - OPEN → → →
COMPARISON CRITERIA			
DEV COST	$ 88M	$ 95M	$111M
5 YR OPS COST	105M	102M	110M
TOTAL COST	193M	197M	221M
BUILDUP RCS	3000 PSI ACCUMULATORS	3000 PSI ACCUMULATORS	CONDITIONING POWER
UNSCHED CONTAM (6 MAN STA)	13.5 LB/DAY	6.6 LB/DAY	22.5 LB/DAY
RESUPPLY SENSITIVITY 6 MAN/12 MAN	5650/6100 LB/90 DAY	5170/5500 LB/90 DAY	6025/6300 LB/90 DAY
OTHER	FLUID STORAGE INTEG	FLUID STORAGE INTEG MAXIMUM SSP UTIL	LOWEST POWER SENSITIVITY

71PDS108533

Concept 11-2 incorporates an open oxygen cycle in that CO_2 reduction (Sabatier) hardware has been deleted and CO_2 is vented overboard at 10- to 14-hour intervals. The delayed venting is required to prevent contamination of the environment during experiment operations. This concept is sensitive to logistics cost variations because of the increased high-pressure oxygen storage and resupply requirements. Concept 11-2 produces twice the venting rates of Concept 8, which led to the selection among the low cost options of Concept 8.

INTEGRATED SUBSYSTEM CONCEPT OPTION 8



51PDS108356

The schematic and the assignment of major hardware to the various subsystems are portrayed in the chart.

The EPS will utilize four regenerative fuel-cell assemblies (two for each volume supplying Bus A and Bus B) each consisting of one fuel cell, electrolysis unit, H_2 accumulator, O_2 accumulator, and 1/2 of a H_2O storage tank. The assembly can receive and/or supply in an emergency H_2, O_2, or H_2O to the ECLSS/RCS.

The ECLSS is a closed O_2 and H_2O concept consisting of an H_2 depolarizer for CO_2 removal, Sabatier for CO_2 reduction, electrolysis for O_2 recovery and for RCS H_2/O_2 generation, and vapor compression for H_2O reclamation. All resupply gases are by 3000-psia, high-pressure storage.

The RCS stores H_2/O_2 gases generated at 300 psia by the ECLSS. The oxidizer/fuel (O/F) ratio has been changed from 3:1 to 8:1, which is the combination ratio of O_2 and H_2 in order to minimize venting.

The integrated subsystem uses an integrated gaseous storage at 300 and 3000 psia.

SELECTED SUBSYSTEMS SUMMARY

INITIAL STATION

SUBSYSTEM	FUNCTION	CONCEPT
EPS	• PRIMARY POWER	• 18.7 KW SOLAR ARRAY - 8000 FT^2
	• SECONDARY POWER	• 7.0 KW REGENERATIVE FUEL CELLS (4)
RCS	• ORBIT MAKE-UP/CMG DESAT	• BIPROPELLANT O_2/H_2 10 LB THRUST
ECLSS	• LEAKAGE MAKEUP; REPRESS; EMERG	• HIGH PRESS. STORAGE, N_2, H_2, O_2
	• CO_2 MANAGEMENT	• HYDROGEN DEPOLARIZER, SABATIER & ELECTROLYSIS O_2 RECOVERY
	• THERMAL CONTROL	• CENTRAL, ACTIVE, DUAL FLUID
G&C	• MOMENTUM EXCHANGE	• DOUBLE GIMBALLED CMG'S (3)
	• NAVIGATION	• 6-GYRO STRAPDOWN IMU, STAR TRACKERS HORIZON TRACKER, SEXTANT TELESCOPE
ISS	• DATA PROCESSING	• CENTRAL PROCESSOR, DATA BUS
	• EXTERNAL COMMUNICATION	• NARROW BEAM STEERABLE K_u BAND; S-BAND & VHF SEMI-DIRECTIONAL
	• COMMAND/CONTROL	• UNIVERSAL MULTI-FORMAT CONSOLES

81PDS110202

The major elements of the subsystems for the MSS are identified on this chart. Elements not discussed previously include the 8000 ft^2 light-weight solar array, which produces 18.7 kw at end-of-life (5 years). The guidance and control function utilizes three double-gimbaled 2000 ft-lb sec CMG's for momentum exchange and relies on strapdown gyros and star and horizon trackers for navigation. A backup manual sextant telescope also provides calibration capability. The information subsystem employs central processing utilizing a data bus concept (2×10^6 BPS) with remote acquisition and control units. Communication with TDRS is through a 5-foot-diameter Ku-band antenna, with S-band to MSFN.

KEY GUIDELINES

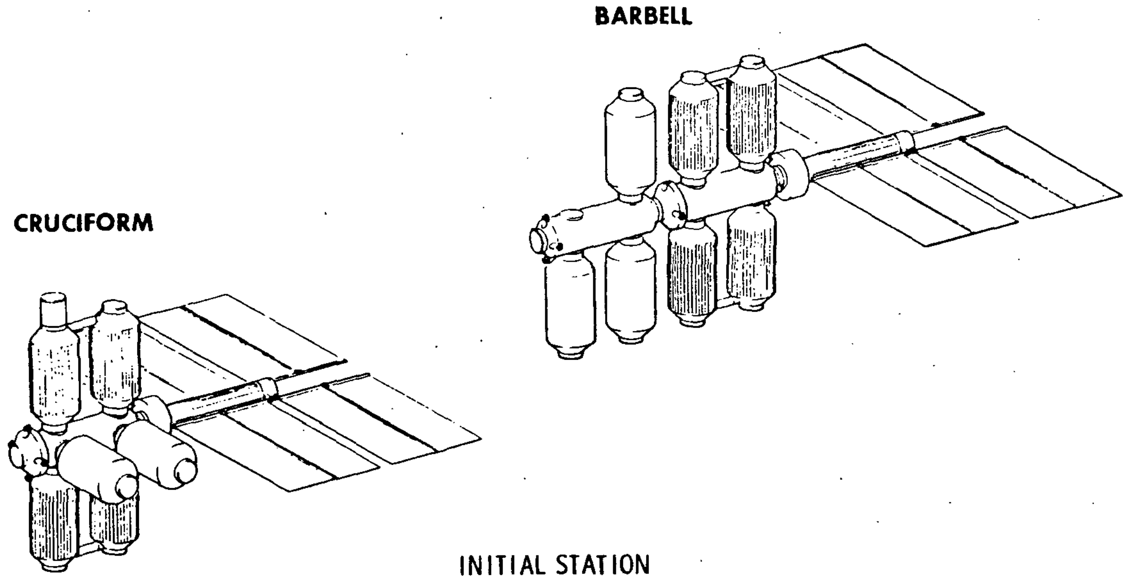
MAJOR CONFIGURATION CONSTRAINTS

◻ MODULE SIZE (1.111, 1.112A)	• 14 FT DIA x 58 FT, 20,000 LB
◻ INITIAL STATION (1.101, 1.105A)	• AT LEAST 6 CREWMEN • GENERAL PURPOSE LAB • AT LEAST 2 RAMS • CAPABILITY FOR GROWTH
◻ GROWTH STATION (1.106)	• 12 CREWMEN • INTEGRAL LAB FACILITIES • RAM SUPPORT PROVISIONS • 33 FT DIA HABITABILITY EQUIVALENT
◻ ISOLATABLE VOLUMES (1.303A)	• 2 SEPARATE, PRESSURIZED, HABITABLE • INDEPENDENT LIFE SUPPORT • ESSENTIAL SERVICES
◻ ENTRY-EGRESS PATHS (B-2.6)	• 2 OR MORE FROM EVERY COMPARTMENT OR AREA WITH RESTRICTED ACCESS
◻ PERSONNEL ESCAPE ROUTES (B-1.2)	• 2 ROUTES FROM EACH HAZARDOUS SITUATION NOT TERMINATING IN A COMMON MODULE AREA

81PDS110203

The configuration concepts of the Phase B studies of both the Saturn-launched and shuttle-launched station have been characterized by three major guidelines: the provision of dual volumes, dual egress, and personnel escape routes. These particular guidelines have been adhered to stringently in the concept analyses as well as in the provisioning of subsystem equipment among the modules.

CONFIGURATION COMPARISON



81PDS110204

As was previously stated, the Phase B Modular Station study concentrated on the barbell configuration with deviation to other configurations as potential solutions to problem areas.

CONFIGURATION SENSITIVITIES

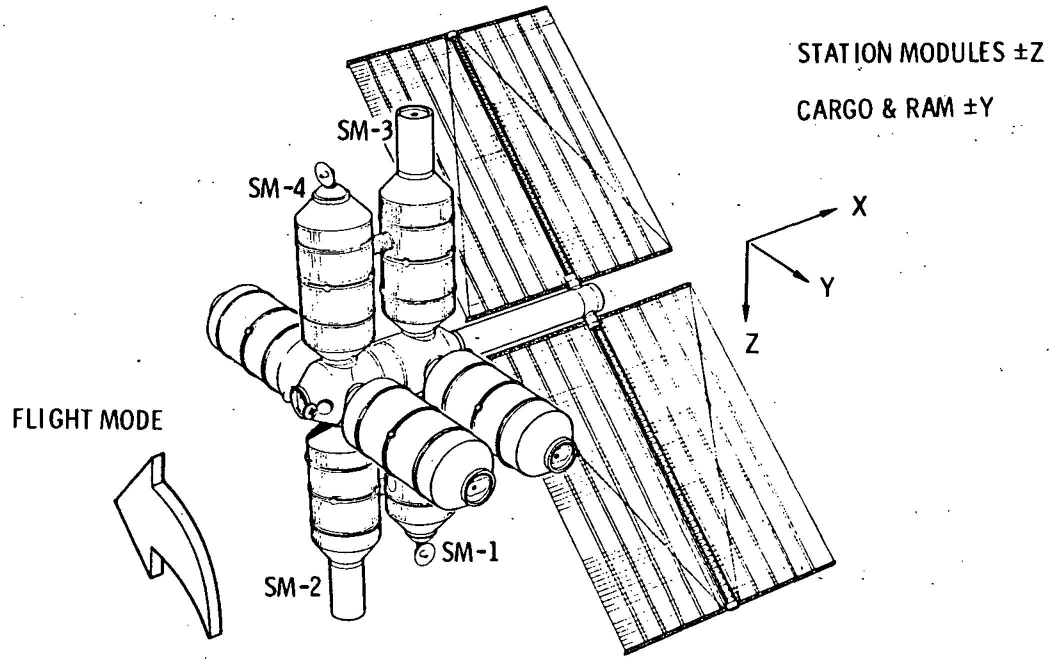
ISSUE	CONFIGURATION	
	BARBELL	CRUCIFORM
REACTION CONTROL		
120 DAY IMPULSE (INITIAL)	1,420,000 LB SEC	688,000 LB SEC
(GROWTH)	1,650,000 LB SEC	932,000 LB SEC
GUIDANCE & CONTROL		
CMG'S	4 AT 4,250 FT-LB SEC	3 AT 2,000 FT-LB SEC
ECLSS		
REPRESS. VOLUME (INITIAL)	20,000 FT^3	11,200 FT^3
STRUCTURE		
NATURAL FREQUENCY	< 0.5 Hz	≈ 1.0 Hz
FLIGHT MODE PREFERENCE		
CMG	X-POP	X-POP OR Y-POP
RCS	Y-POP	X-POP OR Y-POP

81PDS110119

The analyses identified several configuration dependent issues that were driving the barbell station design to an unwieldy and highly complex system. The impulse requirements for the barbell, which are reflected in gaseous storage accommodations, approximately doubled those required for the cruciform. High momentum exchange requirements also were identified for the barbell. The configuration analyses resulted in two core modules for the initial station, resulting in a repressurization volume for the barbell of almost twice that of the cruciform. Of major concern was the natural frequency of the barbell, which maximized at less than 1/2 Hertz against a desired greater-than-1 Hertz. A further complication existed in that for the barbell: CMG's desired an X-POP mode, while the RCS desired a Y-POP mode.

SELECTED CONFIGURATION

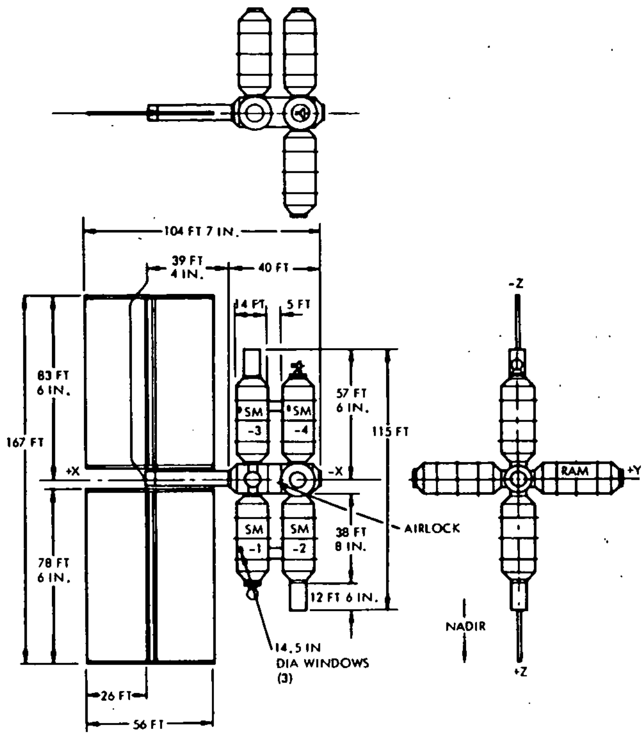
INITIAL STATION



/1PDS110015

The cruciform was selected for preliminary design because of the major reductions in the influencing parameters previously discussed. The special modules required for the initial station are the 40-foot core and the 37-foot power module. Four station modules (denoted as SM-1 theough SM-4) are common modules. Cargo and RAM modules, located on the Y-axis ports, are potentially common modules as well.

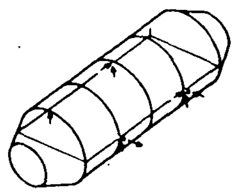
INITIAL STATION DIMENSIONS



81PDS110206

The initial station dimensional characteristics are shown on this chart. Dimensions of RAM and cargo elements are potentially the same as those of the station module.

STATION MODULE DESIGN DRIVERS

• UNIVERSAL STRUCTURAL CONCEPT	PRESSURE SHELL - PRIMARY STRUCTURE FLOOR - SECONDARY STRUCTURE
• RADIATION PROTECTION	90 DAY DOSE CRITERIA
• CRASH CONDITION	LOAD FACTORS (ULT) N_X +8.0, -1.5 N_Y ±1.5 N_Z +4.5, -2.0
• OPERATING PRESSURE	14.7 PSI
• DESIGN WEIGHT	25,000 LB
• SIZE	14 FT DIA SHELL 15 FT DIA LOCAL PROTRUSIONS
• SHUTTLE PAYLOAD BAY INTERFACE	

81PDS110207

The common module is required to accommodate several primary conditions. It is designed such that the pressure shell assumes all primary structure loads. Floors and partitions are thus secondary structural elements. In addition, the structure must provide radiation protection on orbit and meet the shuttle orbiter crash-landing condition in the event of return from orbit or abort from delivery.

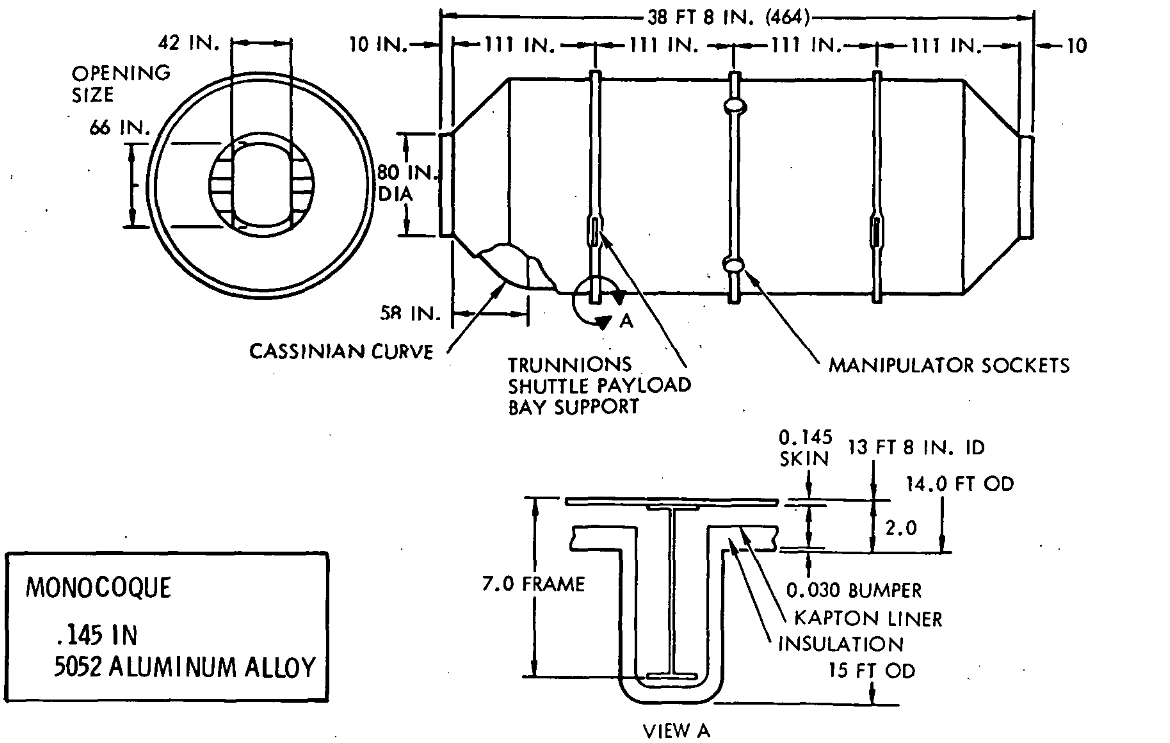
RADIATION PROTECTION

CRITERIA (GUIDELINE)	DOSE RATE (NASA TMX 53865)	PROTECTION
90 DAY EXPOSURE	1 gm/cm^2 (THICK ENDS)	+25% (ALLOW FOR ENDS) ≈ 0.175 ALUM EQUIV
SKIN 105 REM	SKIN EARTH TRAPPED 39.2 REM GALACTIC COSMIC .7 REM SOLAR FLARE 61.0 REM TOTAL 101.0 REM	√
EYE 52 REM	EYE EARTH TRAPPED 39.2 REM GALACTIC COSMIC .7 REM 40.0 REM SOLAR FLARE 61.0 TOTAL 101.0 REM	√ (NORMAL) GOGGLES DURING SOLAR FLARE EVENT
MARROW 35 REM	MARROW 10 REM	√

81PDS110091

The radiation criteria for the modular station is established by the Guidelines and Constraints document. Making use of the NASA TMX 53865, adequate protection from earth-trapped, galactic cosmic, and one solar flare radiation for skin and marrow can be achieved with a structure possessing a 1 gm/cm^2 density. Goggles will be required to protect the eyes from the solar flare. Because the source data was for thick ends of a cylindrical vehicle (100 gm/cm^2), a safety factor of 25 percent was added by NR. The resultant 1.25 gm/cm^2 can be achieved with an equivalent of 0.175 aluminum and provides omnidirectional radiation protection.

STATION MODULE STRUCTURAL ARRANGEMENT



81PDS110208

The module has been designed for low-cost monocoque construction using 0.145-inch 5052 aluminum alloy augmented by an 0.030-inch aluminum meteoroid bumper. Three frames are utilized external to the pressure shell, which accommodate the shuttle attach points and manipulator sockets. Kapton-lined insulation is located inside the meteoroid bumper and acts as a secondary bumper.

FUNCTIONAL ALLOCATIONS

CREW/HABITABILITY REQUIREMENTS

(1) PRIVATE AREAS (E.G., STATEROOMS) SHOULD BE AWAY FROM HIGH TRAFFIC/NOISE AREAS (E.G., AISLES, DINING-RECREATION)

(2) FLEXPORTS SHOULD ENTER INTO PUBLIC AREAS

(3) GALLEY AND DINING ADJACENT FACILITIES

(4) PERSONAL HYGIENE SHOULD BE NEAR STATEROOMS

(5) CONTROL CENTERS SHOULD BE NEAR STATEROOMS

(6) DIMENSIONAL CRITERIA (CEILING HEIGHT 82 IN. MAIN DECK GENERAL MOBILITY AREAS)

81PDS110209

Early in the study, a detailed analysis was conducted to establish those functions that required adjacency, those that were improved by adjacency, and those that required separation. The privacy of staterooms and the traffic flows associated with crew activities were established generically, and these requirements were imposed on the design. Mitigating factors, such as subsystem separation between volumes and the restrictions imposed by floor area per module, resulted in some compromises.

SELECTED ALLOCATIONS

INITIAL STATION

VOLUME 1

	CREW/CONTROL (SM-1)	
ABOVE DECK	COMMANDER/EXEC STATEROOM CONTROL CENTER & DATA ANALYSIS BACK-UP MEDICAL PERSONAL HYGIENE	1 4 5
BELOW DECK	CREW STATEROOMS (2) WASTE MANAGEMENT EQUIPMENT STORAGE	

	LAB/DINING/ATMOSPHERE MGMT (SM-3)
ABOVE DECK	PHYSICS BIOMED LAB ZENITH AIRLOCK GALLEY & WARDROOM
BELOW DECK	AIR REVITALIZATION EQUIPMENT STORAGE

VOLUME 2

	LABORATORY/ATMOSPHERE MANAGEMENT (SM-2)
ABOVE DECK	MECHANICAL LAB OPTICAL/ELECTRICAL LAB. BIOSCIENCE/EARTH OBSERV LAB. NADIR AIRLOCK BACK-UP GALLEY
BELOW DECK	AIR REVITALIZATION EQUIPMENT STORAGE

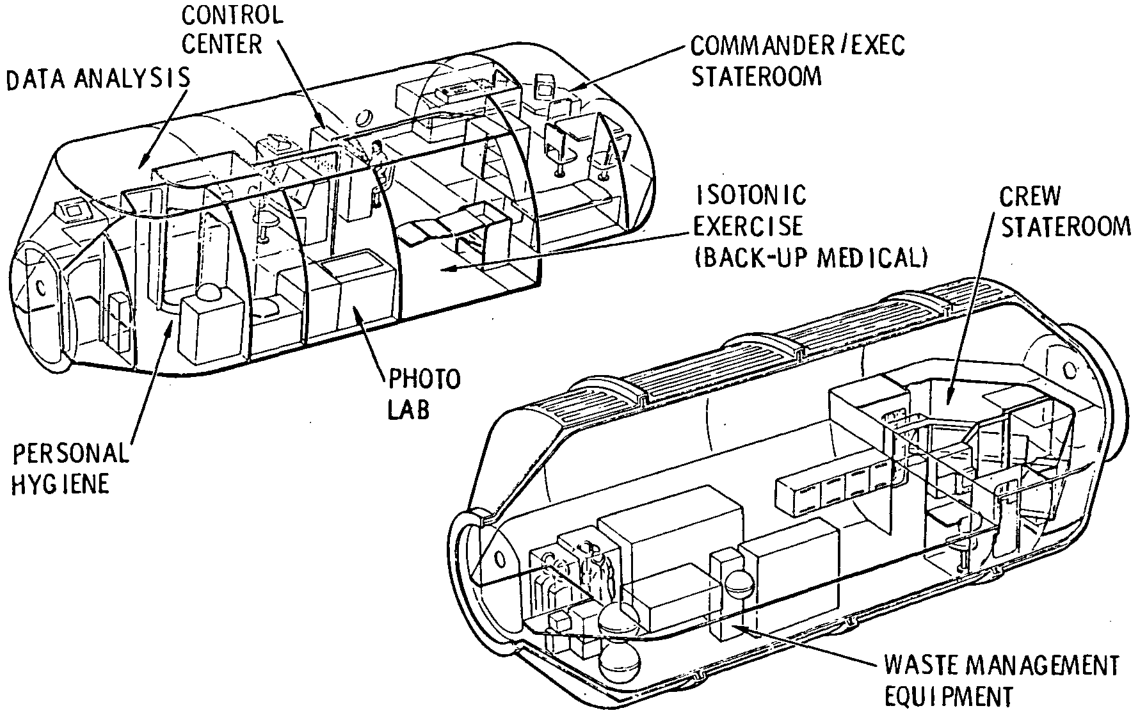
	CREW/CONTROL (SM-4)	
ABOVE DECK	COMMANDER/EXEC STATEROOM CONTROL CENTER MEDICAL & CREW CARE PERSONAL HYGIENE	1 4 5
BELOW DECK	CREW STATEROOMS (2) WASTE MANAGEMENT EQUIPMENT STORAGE	

81PDS110210

Accommodation of the requirements denoted in the previous chart are exemplified by the circled numbers on this chart. It should be noted that despite deactivation of a volume, the remaining volume retains the function of crew quarters (double occupancy), control, waste management, air revitalization, medical, and food.

CREW / CONTROL

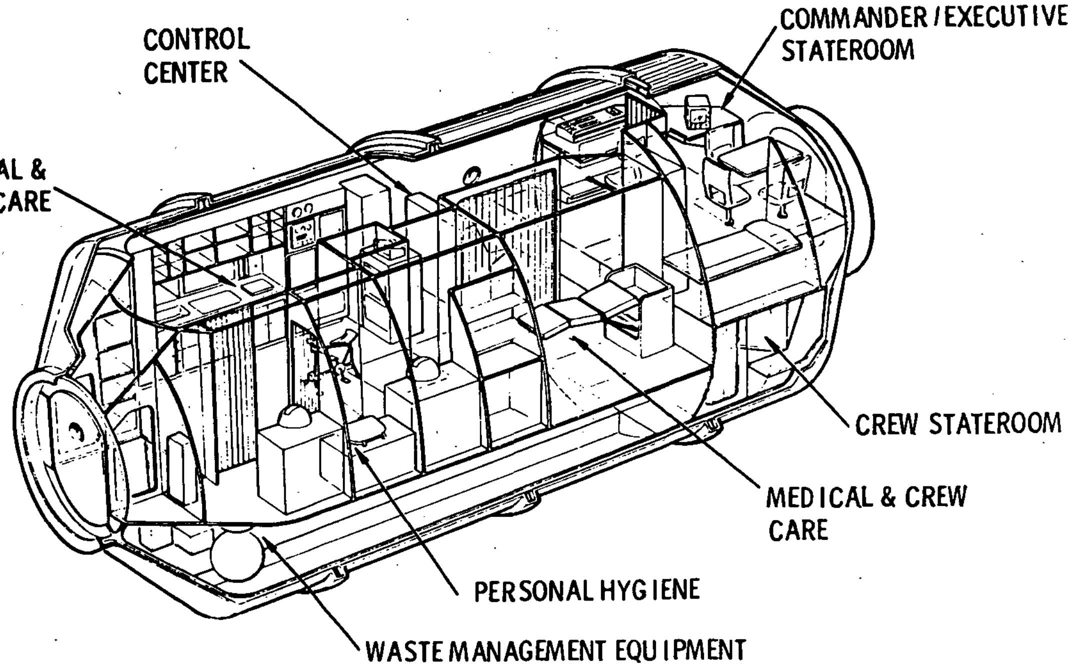
MODULE 1



81PDS110211

The crew/control module (SM-1) contains a commander/executive type stateroom and two crew staterooms. These are provided in a split-level arrangement and have been mocked up by NR to assure their acceptability. The waste management equipment is located below deck near the personal hygiene area, which precludes the existence of a sewage system. The control center, data analysis, and the photo laboratory occupy the remainder of the upper deck area.

CREW / CONTROL
MODULE 4

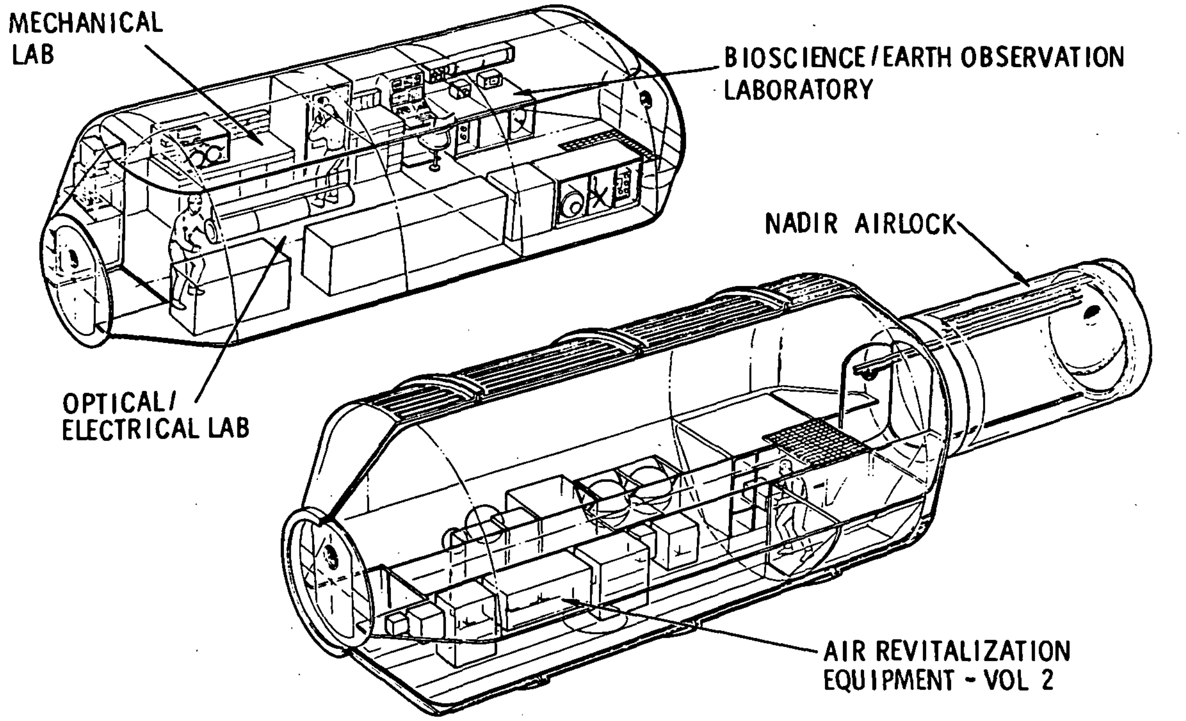


81PDS110212

Module SM-4 is essentially a duplicate of SM-1 in relation to staterooms, hygiene, and the control center. The medical and crew care function has been incorporated in this module.

LABORATORY / ATMOSPHERE MANAGEMENT

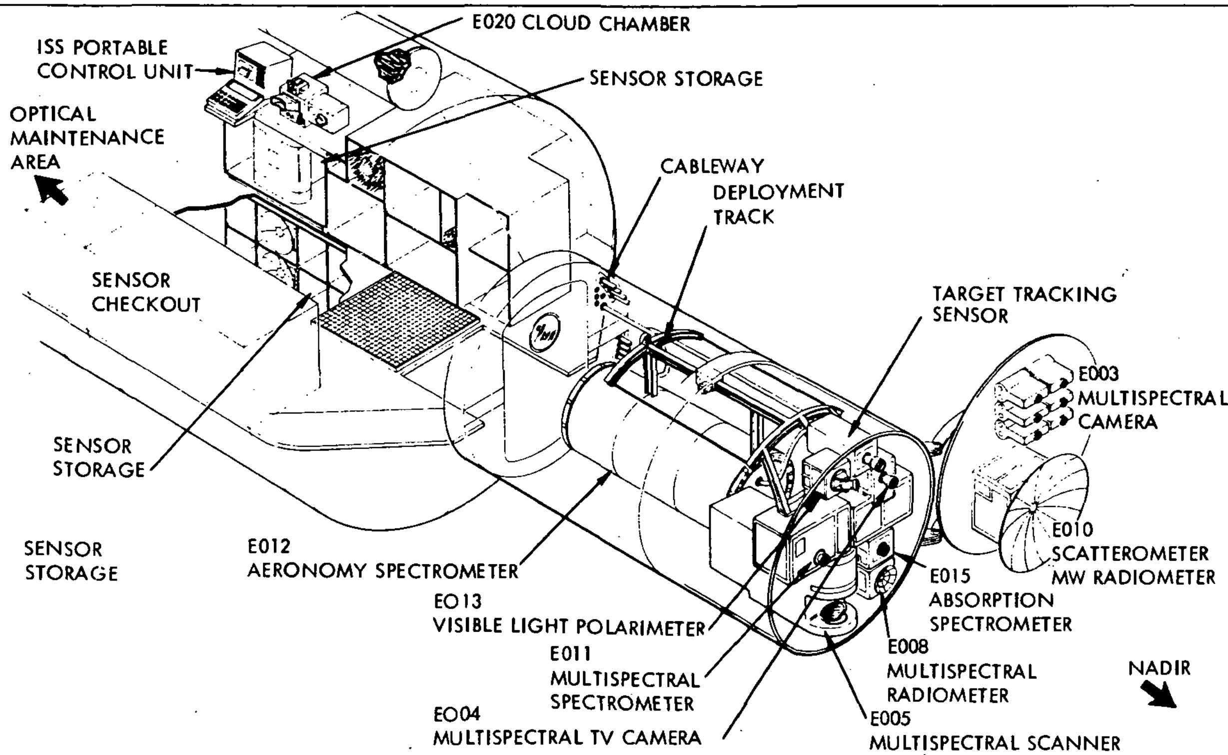
MODULE 2



81PDS110213

The laboratory module also houses the air revitalization equipment (CO_2 management and atmosphere control). Module SM-2 incorporates the mechanical and optical/electrical general purpose laboratory area and provides an area for the earth observation laboratory and biosciences (not simultaneously). The nadir airlock is located at the end of this module.

SM-2 GPL TYPICAL OPERATIONS

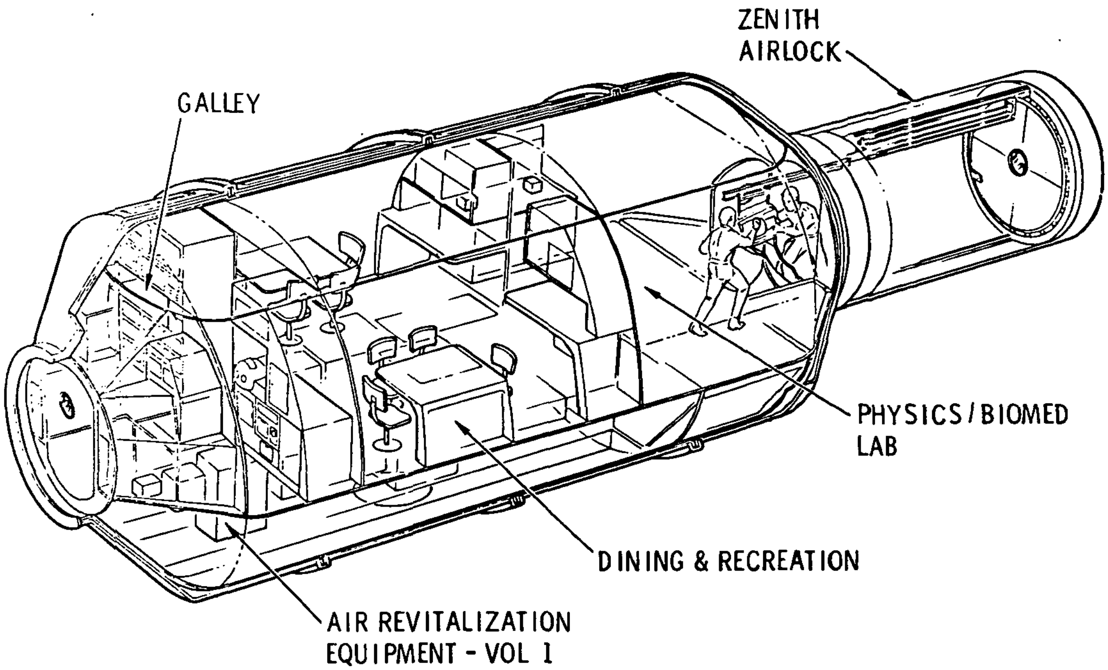


71PDS108466

The installation of earth observation equipment is shown in this chart. Stowage of sensors not in use is provided, and control of the experiment is accomplished through a portable control unit of the information subsystem.

LABORATORY / DINING / ATMOSPHERE MANAGEMENT

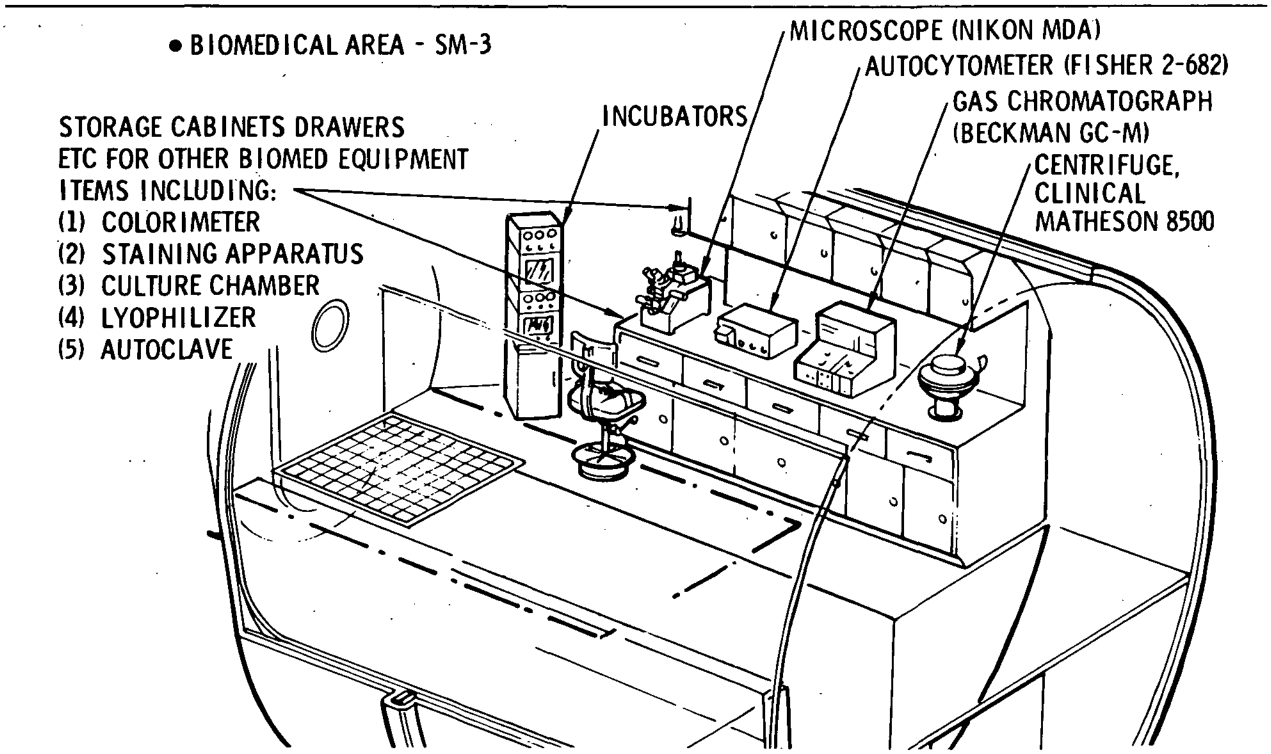
MODULE 3



81PDS110214

The remaining module (SM-3) provides laboratory facilities for the physics and biomedical experiments. The zenith airlock is located at the laboratory end. The air revitalization equipment for Volume 1 is below deck in this module, and the galley and dining functions are located above deck.

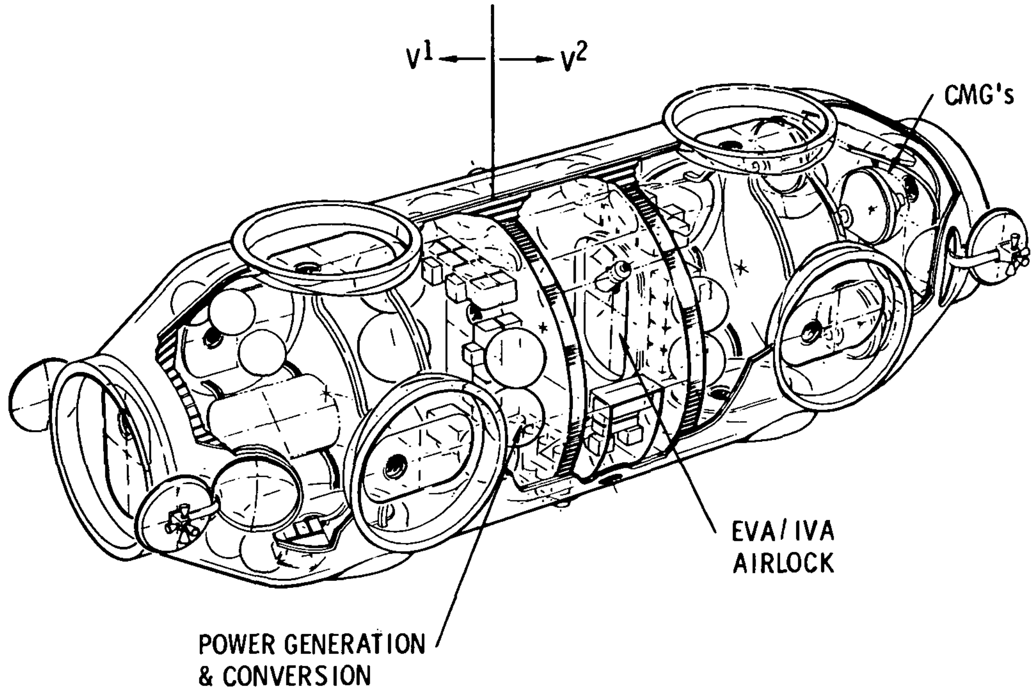
EXAMPLES OF COMMERCIAL EQUIVALENTS



71PDS108468

The installation of biomedical equipment in the SM-3 laboratory is shown on this chart. This particular installation represents the use of existing or slightly modified commercial equipment.

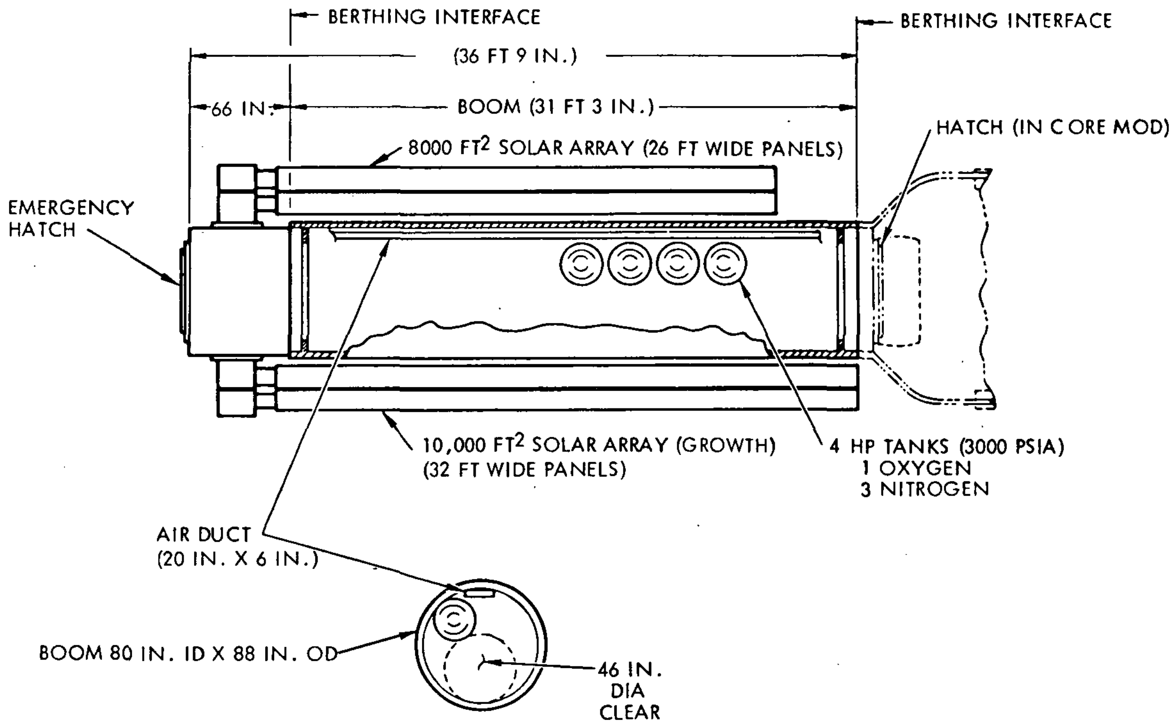
CORE MODULE



71PDS110022

The core module is separated into two compartments by a central EVA/IVA airlock. Fuel cells, inverters, and electrolysis units are located on the airlock bulkheads in each compartment. Low-pressure accumulators (300-psi) for the EPS and RCS are installed in the core. Installation of the guidance and control trackers and gyros is provided, and the CMG's are positioned near the RAM docking port.

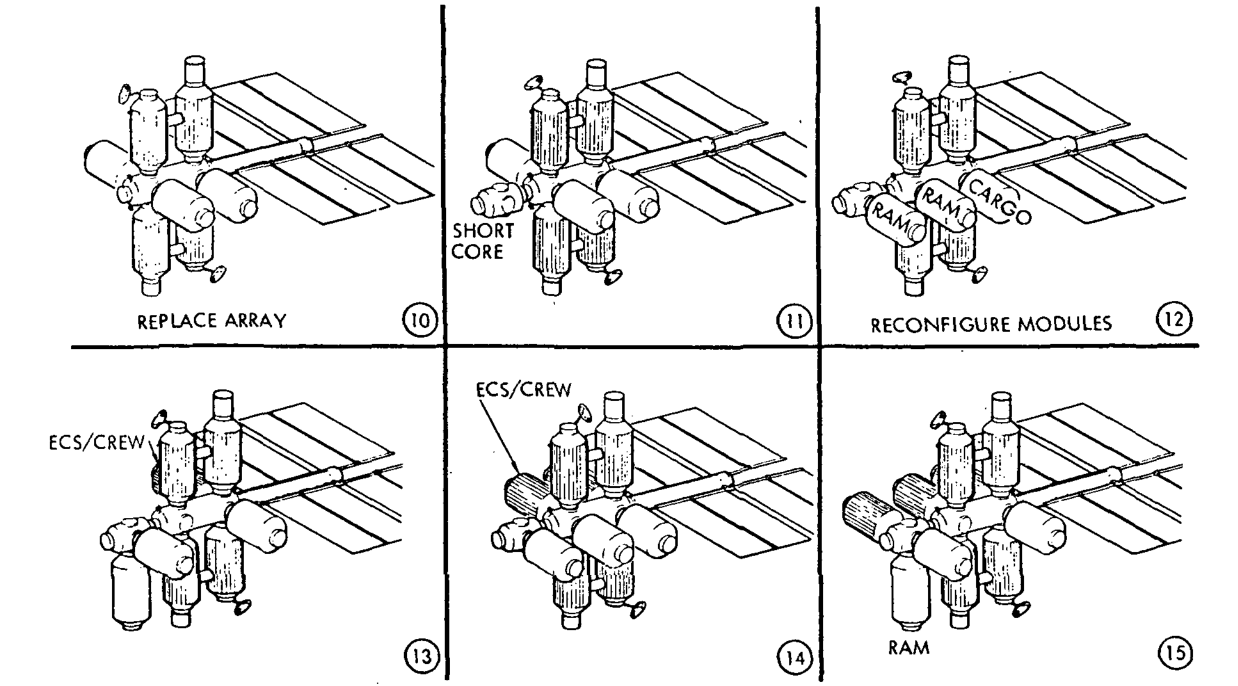
POWER MODULE



81PDS110215

The power module contains four high-pressure tanks for repressurization of one module of the station. The solar arrays in the retracted position are within the 14-foot envelope, and the turret/array combination is removable for array replacement.

BUILDUP TO GROWTH



81PDS110216

Growth station capability is achieved by the addition of two station modules with crew quarters and life support and by the addition of a short core with added fuel cell/electrolysis equipment. The solar array is replaced with a 10,000-square-foot array.

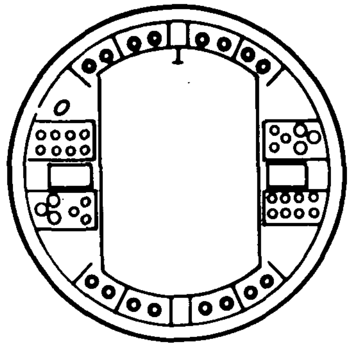
SOURCES OF COMPLEXITY

MODULAR CONCEPT	• INTERMODULE DEPENDENCY • VOLUME UTILIZATION EFFICIENCY • EMERGENCY PROVISIONS • GROUND CHECKOUT
BUILDUP	• SHUTTLE-TO-MODULE INTERFACE • MODULE DELIVERY/EMPLACEMENT • SHUTTLE LAUNCH FREQUENCY • CHECKOUT & QUIESCENCE
GROWTH	• INITIAL STATION SCAR • BUILDUP DELAY

71PDS110077

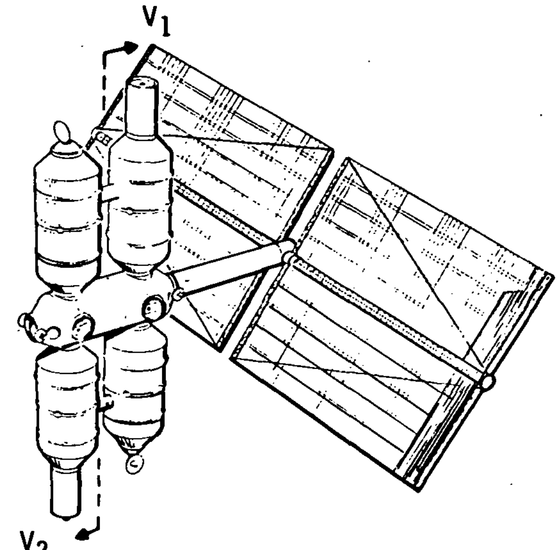
Complexity of the modular space station derives from several sources: (1) the modularity of the vehicle presents unique requirements for which solutions tend toward the complex; (2) the process of buildup fosters operational complexity as well as design complexity; and (3) the requirement for growth after a period of operation at an initial plateau presents additional complex issues at the programmatic and design level.

COMPLEXITY ISSUES



INTERMODULE DEPENDENCY

- POWER DISTRIBUTION
- THERMAL CONTROL
- INFORMATION TRANSFER
- REMOVAL / DEACTIVATION



EMERGENCY PROVISIONS

- REPRESSURIZATION
- V_1/V_2

81PDS110217

It would be desirable from a design and operational viewpoint to create a configuration in which each module is self-contained and completely independent. The power requirements of individual modules are of sufficient magnitude that individual power supplies are impractical, however, and data and command interchange between modules is unavoidable and in some cases mandatory. These requirements and others impose the need for transfer of power, information fluids, and gases across the berthing interface. The availability of utilities at the interface also is fundamental to the station support function for the experiments. Without this support the experiment modules (RAM's) would be forced to provide their own utilities with the weight and complexity that follows.

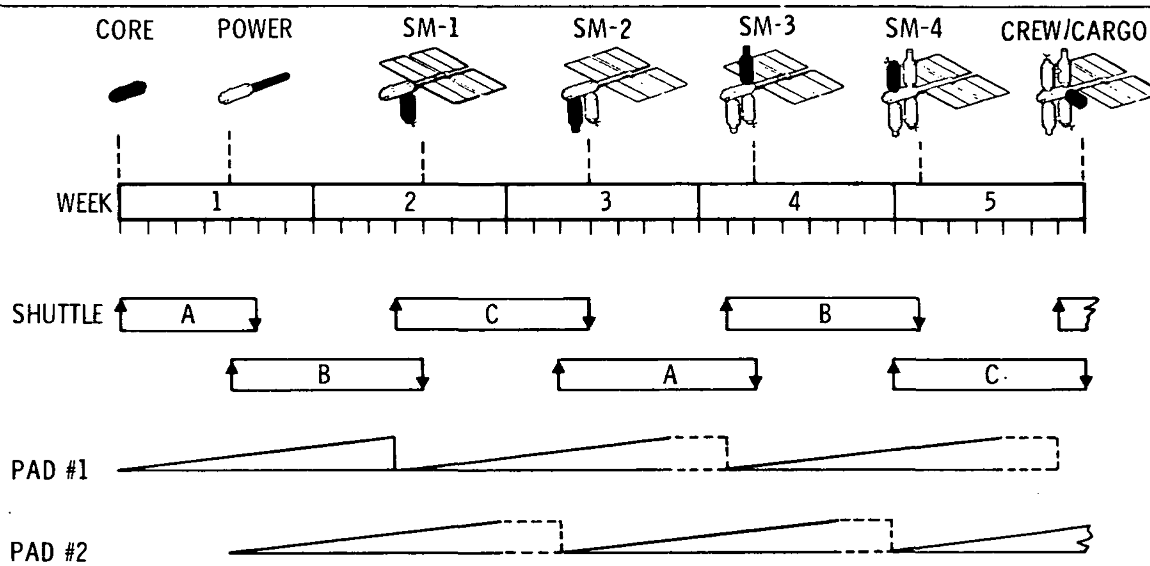
The emergency provisions for the modular station are no more stringent than those required for the 33-foot station. However, certain of these create complex arrangements, both internal and external, which lead to further analysis of the justification for the requirement. The repressurization stores at the station are provided to permit repressurization of either volume following its evacuation. The need for evacuation based on an accident or malfunction is not questioned; however, following repressurization, a shuttle mission is required immediately to replenish these stores.

Because the mission is unavoidable, repressurization through resupply by a logistic mission appears to be a viable approach, thus eliminating the complexity of storage, control, monitor, etc., from the basic station and permitting these functions to be done on the ground.

The precept of two separate isolatable volumes has existed since the initiation of the Phase B studies. This "volume" division produces complicated arrangements in subsystems and habitable areas and essentially controls the locations of functions. In neither the 33-foot station study nor the modular study has NR deviated from this requirement; however, the potential of simplicity in operation (while retaining the element of crew safety desired) could perhaps be achieved by providing a refuge area while corrective measures are employed.

INCREASED LAUNCH FREQUENCY

BUILDUP POTENTIAL



- DELETE ALL BUILD-UP SCAR
- IOC 35 DAYS AFTER 1ST LAUNCH

81PDS110112

The launch frequency of one shuttle flight in 30 days has created buildup scars in the configuration. The 300-psi accumulators must be increased to the 3000-psi capability for buildup; a special atmosphere monitor system is required in the core; special batteries, inverters, and a unique information and RF command system are needed. A less complex approach maximizes the shuttle launch frequency during buildup (through the use of three orbiters) and eliminates all scar. With the projected time period of the modular station relative to the orbiter IOC, this approach appears practical.

IV. FUTURE ACTIVITIES

IV. FUTURE ACTIVITIES

MODULAR SPACE STATION-PHASE B
NASA HEADQUARTERS-QUARTERLY REVIEW

INTRODUCTION

R. BERGLUND

OVERVIEW
SORTIE ANALYSIS
EXPERIMENT ANALYSIS

E.G. COLE

MSS REVIEW
OPERATIONS
SUBSYSTEMS
CONFIGURATIONS

A.A. TISCHLER

FUTURE
ACTIVITIES

E.G. COLE

81PDS110180

MSS SECOND QUARTER CONCLUSIONS

EXPERIMENT CAPABILITY PLATEAUS → PROGRAM FLEXIBILITY

SORTIE PAYLOADS → COMMONALITY AND EVOLUTION POTENTIAL

LONG BUILD-UP & GUIDELINES → COMPLEXITY AND SCARS

SUBSYSTEM SELECTION → LOW COST AND EFFICIENT

CRUCIFORM CONCEPT → MINIMIZES DESIGN REQUIREMENTS

81PDS110221

The activities to date have established that a minimum cost program of experiments can be achieved by utilizing the plateaus developed and that sortie payloads can be potentially evolutionary toward those plateaus in both objective accomplishment and system/subsystem equipment commonality.

It has been seen that the buildup frequency and the requirements defined by the guidelines have produced complexity and scars that can be minimized by guideline changes with minimum compromise.

The subsystem selections reflect the use of low development cost plus low operational costs for the initial five years of operation, and, by selection of the cruciform concept, the demands on these subsystems have been considerably reduced.

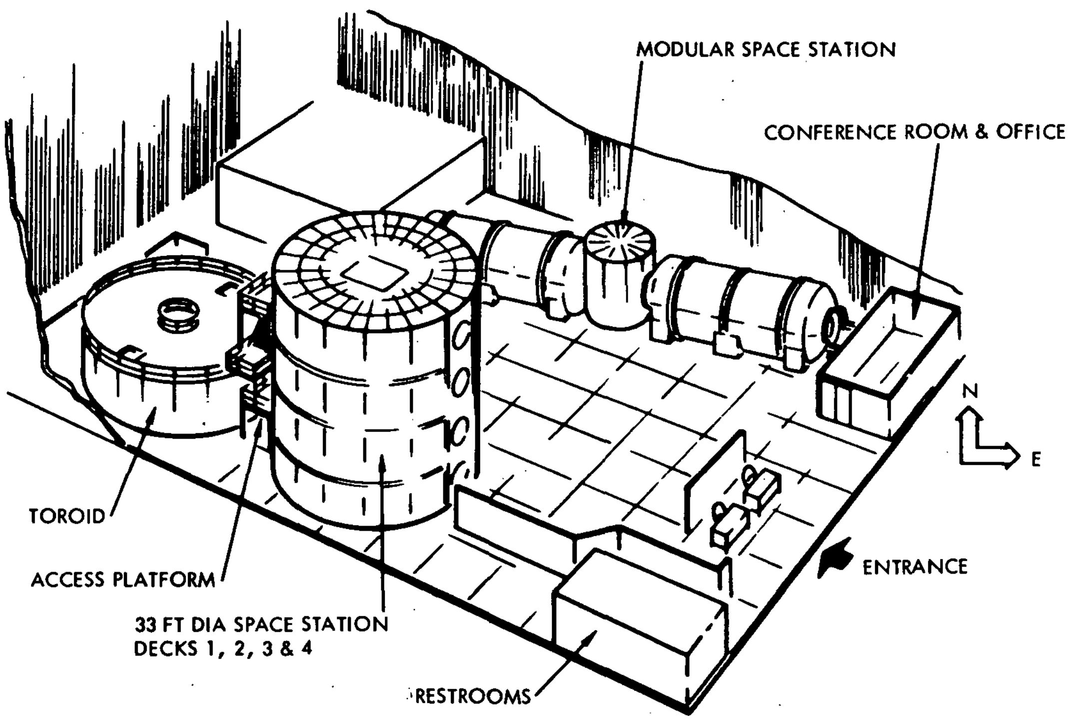
FUTURE ACTIVITIES

REDUCED PAYLOAD SIZE IMPACT STUDY COMPLETION	1 SEPTEMBER 1971
PRELIMINARY DESIGN COMPLETION	29 SEPTEMBER 1971
SORTIE FINAL CONCEPTS INTEGRATION	1 OCTOBER 1971
NASA EARTH ORBITAL SYS TECHNOLOGY TEAM REVIEW	6 OCTOBER 1971
MOCKUP COMPLETION	30 OCTOBER 1971
MSS THIRD QUARTERLY REVIEW	4 NOVEMBER 1971
MOCKUP REVIEW	23 NOVEMBER 1971
NASA HEADQUARTERS REVIEW	30 NOVEMBER 1971

81PDS110219

The remaining activities for the Space Station Phase B extension are listed. The payload reduced size impact study will be completed 1 September 1971 and documented by 17 September 1971. An item of note is the Technology Team review now scheduled for 6 October. The mockup review at the end of November will be documented approximately one month later.

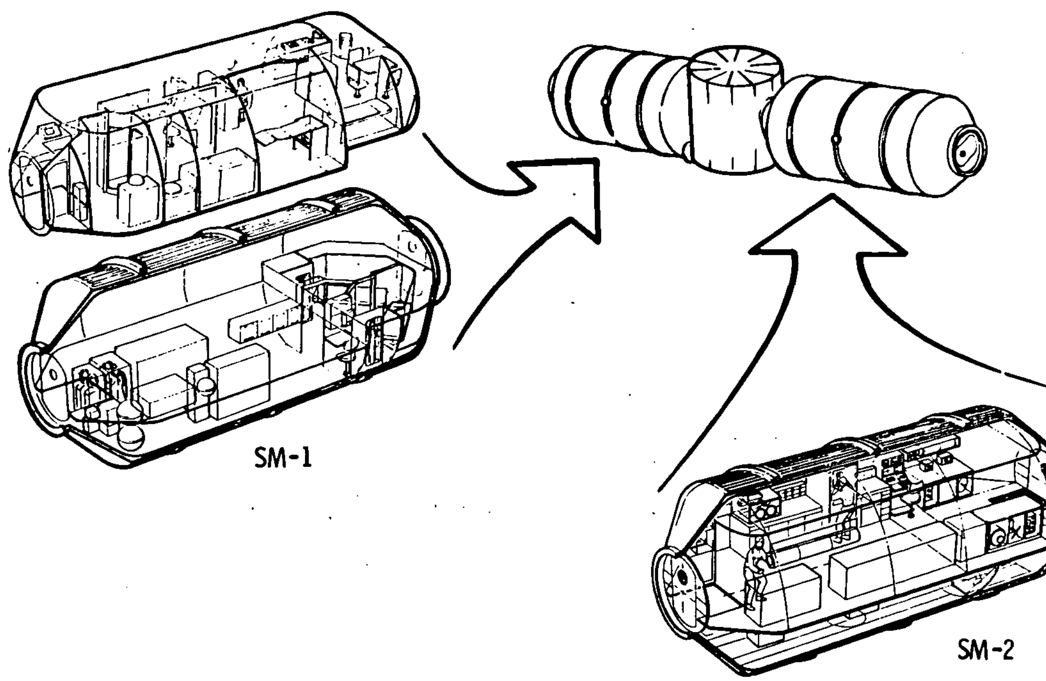
MSS MOCKUP & DISPLAY AREA



71PD110028

The mockup of the NR modular space station will be located adjacent to the 33-foot-diameter mockup, which is housed at Seal Beach, California. Two station modules and representation of a partial core module will be mockedup.

MOCKUP CONFIGURATION



71PDS1.10113

The modules selected for mockup are: (1) the crew/control module (SM-1), which houses the data analysis and photo laboratory, and (2) the laboratory module SM-2, which incorporates the mechanical, optical laboratories, and the earth observations laboratory.

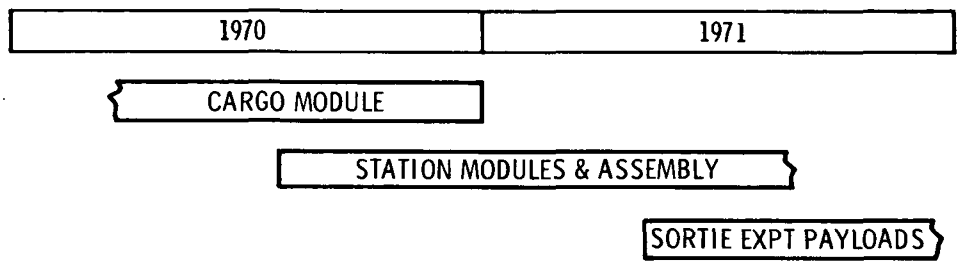
PROGRAMMATIC CONSIDERATIONS

SINGLE ORBIT (6 TO 12 MAN GROWTH) VS TWO ORBITS (ONE 6-MAN EACH ORBIT)

GUIDELINE RE-EVALUATION - BUILDUP PHILOSOPHY

- EMERGENCY PROVISIONS

INFLUENCE OF EXPERIMENT ACCOMMODATION AND OPERATION ON SHUTTLE INTERFACE



81PDS110222

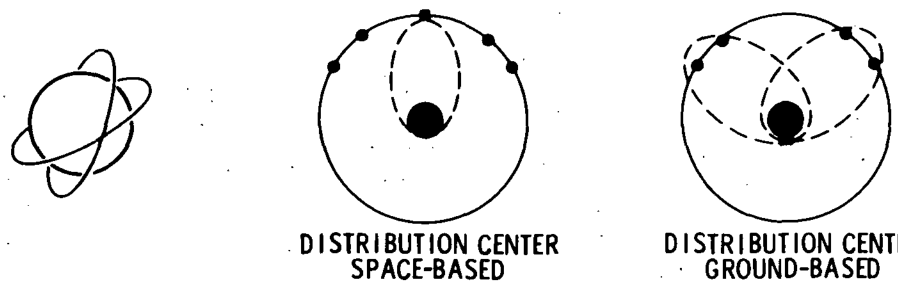
In conducting the Space Station studies, several concepts have arisen that should be given consideration in future programmatic studies. First, the desirable experiment orbital parameters indicate that there are possibly two regimes (orbital inclination) instead of one in which the experiments would like to be operated. Therefore, instead of increasing the size of the initial station to 12, a more effective operation might be to have two six-man stations in different orbits.

Sensitivities studies of the guidelines imposed on the Modular Space Station have shown that the buildup philosophy and emergency provisions can be a major design driver; therefore, consideration of buildup as a short-duration, high-activity, single-program event should be given serious consideration. Also, with three or four years of operational Shuttle experience completed, the need for certain emergency provisions onboard the Station should be given special attention. Ground basing of these emergency provisions may be more than adequate.

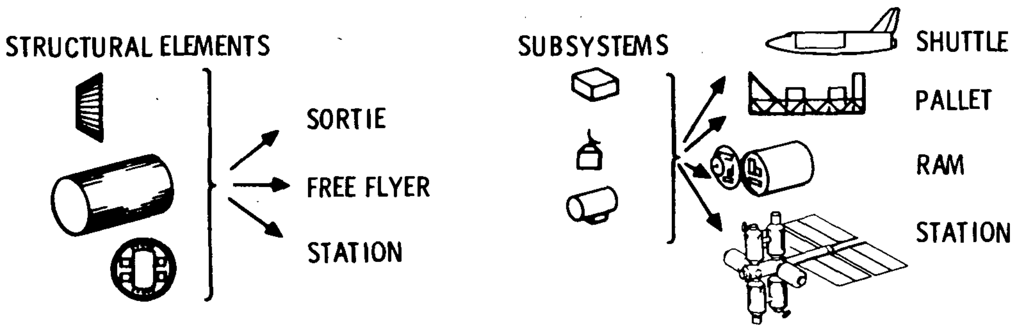
Another area that appears to need greater definition and understanding is the impact of experiment accommodation and operation on the Shuttle interface. NR first uncovered interface problems when they were conducting the cargo module conceptual design in the option period to the original Space Station study. Although the cargo module interface was simple in design, it did uncover many design and operational constraints. The most in-depth study of station modules as payloads and the role of the Shuttle in Station assembly has provided additional requirements to that interface. The recent sortie experiment payload analysis has indicated an even more complex interface and critical requirements imposed on the Shuttle as it tends to approach the role of a 7-day Space Station. The degree to which the Shuttle design and operations are compatible with experiments can have a great influence on the operational complexity and total program cost.

PROGRAMMATIC CONSIDERATIONS (CONT)

? OPERATIONAL LOGISTIC MODEL ?



? EFFECTIVENESS OF COMMONALITY & EVOLUTIONARY DEVELOPMENT ?



81PDS110223

Although analyses show that a large portion of the Blue Book experiments can be accommodated by the Shuttle, the inherent increased effectiveness of a space-based distribution center is not too well understood or has not been adequately defined. It may be more efficient to operate certain experiments on a Space Station or to utilize a Space Station as a service distribution center for free-flying modules. This simplifies the payload and scheduling of Shuttle flights on the ground with the variation in requirements being satisfied at the Station. The other mode is to have the distribution center located on the ground and each mission configured for its special service and maintenance sortie. The possibility of just transporting a simple fluid such as water to orbit and to transform the water to hydrogen and oxygen fuel for the use of a centralized power source could be a much simpler operation than cryogenic transfer in orbit.

The effectiveness of a commonality or evolutionary program is very difficult to assess and is dependent upon the program structure. For example, if all the elements to be developed are part of one program, then it is easy to determine the proper cost reduction. However, if the common elements or evolutionary elements are related to different programs, then it is very difficult to define and achieve the increased effectiveness because of arguments over which program will support the initial development cost.